542 September 15, 1999

TO: 542/Chief Engineer, Systems Analysis Branch

FROM: 542/Head, Structural Loads and Analysis Group

SUBJECT: Evaluation of Damping Treatment Applied to MAP Spacecraft to Reduce High Thruster Response from Acoustic Excitation

REF:
(a) "Fabrication of Damped Spacecraft Equipment Panels", K.A. Schmidt, F. Curtis, E. Muziani, L. Amore, Vibration Damping Workshop II, AFWAL, March 1986
(b) "Analysis and Experimental Evaluation of RELSAT Damped Equipment Panels", C.V. Stahle, J.A. Staley, and J.C. Strain, Vibration Damping Workship II, AFWAL, March 1986
(c) "Finite Element Prediction of Damping in Structures with Constrained Viscoelastic Layers", C.D. Johnson, andD.A. Kienholz, AIAA Journal,Vol 20, No. 9, Sept 1982, pp. 1284-1290

SUMMARY

An acoustic test of the MAP spacecraft bus was performed on August 27, 1998. Evaluation of the responses measured at thruster locations on the top deck indicated that these locations would experience accelerations that would significantly exceed the levels to which the thrusters had been qualified. Because of schedule and cost constraints, it was not possible to have the thrusters re-qualified to the higher vibration levels. The approach taken to resolve the problem was to apply damping treatments to the spacecraft to reduce the acoustic response.

A modal survey of the spacecraft was performed to identify the structural modes that were causing the high response at the thruster locations. Once these modes had been identified and correlated with analytical models, analysis was performed to optimize the use of constrained layer damping treatments on the spacecraft. Two types of damping materials were used in this application. A thin Visco-Elastic Material (VEM) with a graphite/epoxy (Gr/Ep) constraint layer was applied in sheets to the thruster mounting bracket and to the top deck of the spacecraft. A thick VEM material with a honeycomb constraint layer was applied in strips to edges of the top deck of the spacecraft. Both damping treatments were modeled analytically. These analytical models were used to optimize the VEM thickness and constraint layer dimensions as well as to predict the expected reduction in response levels at the thruster locations.

A second acoustic test of the MAP spacecraft with the damping treatments in place was performed on July 1, 1999. The purpose of this test was to measure the reductions in vibration response at the thruster locations as a result of the damping treatments. The test configuration included a significant number of flight components, electrical harnessing, and thermal blankets that were not

present in the initial spacecraft acoustic test. A review of the acceleration levels after the test showed that while the reductions achieved were less than predicted by analysis, they were significant enough to show that the top deck thrusters had been adequately qualified for the flight acoustic environment.

This memo summarizes the analysis that was performed to define the damping treatments applied to the MAP spacecraft and to predict the reduction in response expected as a result of their implementation. The memo also compares the response data measured during both acoustic tests to evaluate the effectiveness of the analytical techniques used to predict the constrained layer VEM damping.

SPACECRAFT LEVEL ACOUSTIC TEST – AUGUST, 1998

The initial acoustic test of the MAP spacecraft was performed on August 27, 1998. The details of the test are given in the "MAP Spacecraft and Solar Array Deployment System Acoustic Test Plan", Wayne Chen/Code 542, dated August 24, 1998. The test configuration consisted of the flight MAP spacecraft bus with mass mockups for various flight components including the thrusters. No thermal blanketing or electrical harnesses were installed for this test. The spacecraft configuration for this acoustic test is shown in Figure 1. The acoustic spectrum for this test is given in Appendix A.

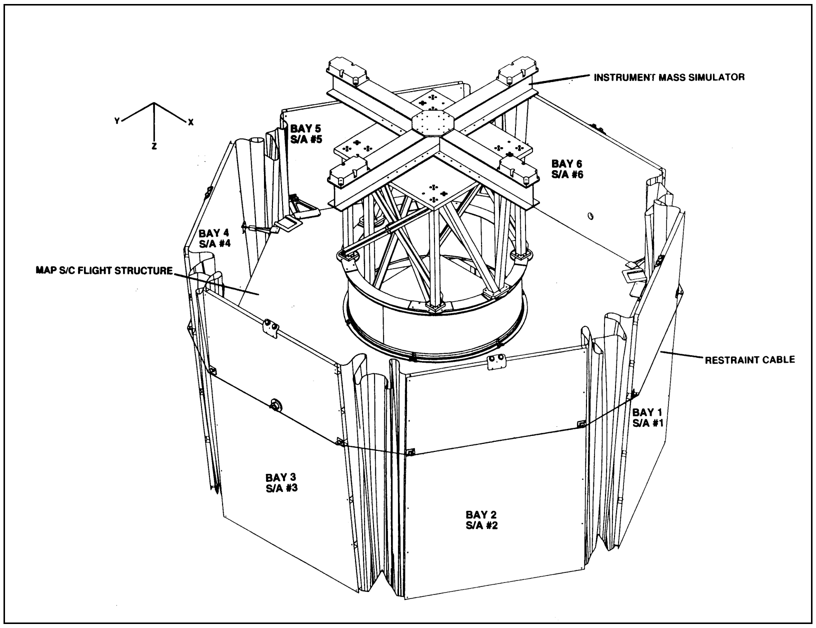


Figure 1. MAP Spacecraft Acoustic Test Configuration

Review of the processed acceleration data after the test showed that the responses measured at the upper deck thruster locations significantly exceeded the thruster random vibration qualification levels. The thrusters had previously been qualified by the thruster manufacturer, PRIMEX Aerospace, to a level of 0.2 g^2/Hz from 20 to 2000 Hz with an overall level of 20 G_{rms}. The response data measured during the test showed a peak PSD level of 116 g^2/Hz with an overall level of 44 G_{rms}. Figure 2 shows the location of the highresponse which occurred at the lower thruster locations on both of the upper deck thruster brackets. Figure 3 shows the acceleration PSD level

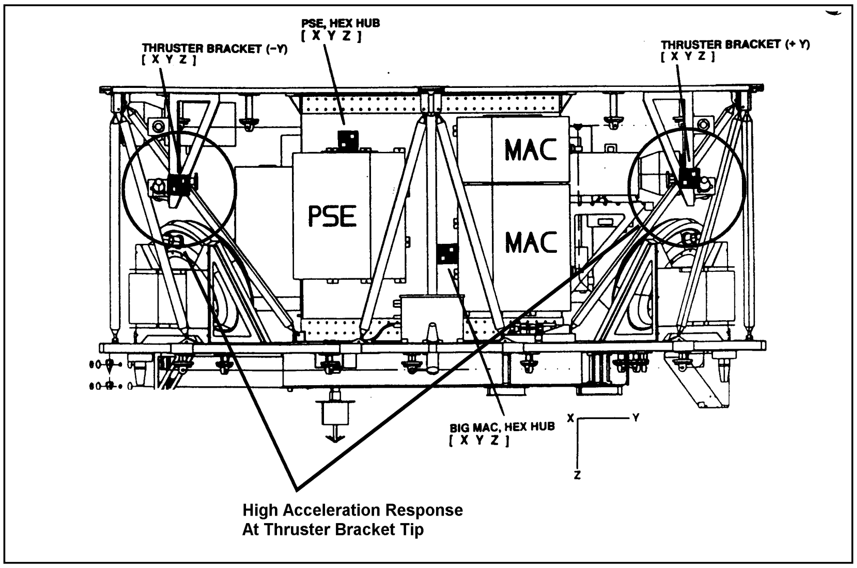


Figure 2. Location of High Thruster Response

which was measured in the y direction at the -Y thruster location during the acoustic test. Also shown in Figure 3 is the random vibration test level to which the thruster had been qualified. It should be noted that the thruster response in the x direction also exceeded the thruster qualification levels however the y direction had the highest PSD levels as well as the highest overall Grms response. Since the focus of this memo is to describe the process used to define and implement the damping treatments on the MAP spacecraft, only the y response is covered in detail. During the acoustic test there were 3 triaxial accelerometers (9 channels) located on the top deck. One triax was located on each of the thruster mockups near the large thruster bracket tip and one was located on the star tracker mockup which is in the center of bay 6 (see Figure 4). The full set of PSD acceleration data measured at these top deck accelerometer locations is provided in Appendix A for reference.

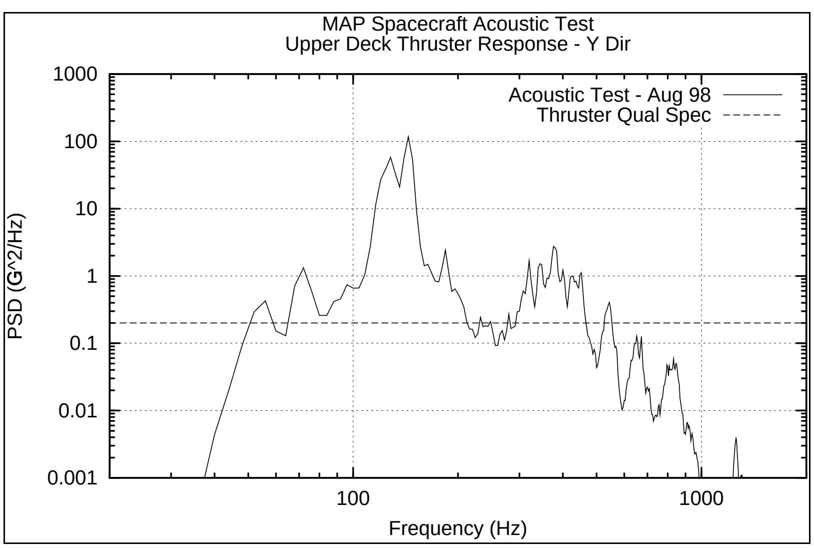


Figure 3. Thruster Qual Spec vs Acoustic Test Response

UPPER DECK THRUSTER CONFIGURATION

There are 4 identical 1-lb thrusters that mount to the MAP spacecraft upper deck. The thrusters mount in pairs to the +Y and –Y side of the spacecraft in Bays 4 & 5 respectively. Each pair of

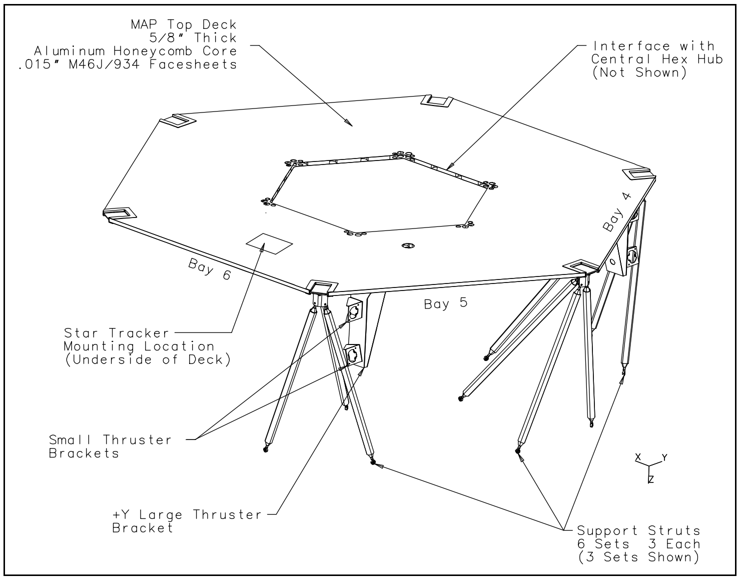


Figure 4. Detail of MAP Top Deck with Thruster Brackets

thrusters consists of an upper (closest to the deck) and lower thruster location. The bracket used to mount the thrusters to the top deck is made up of three parts, two "small" brackets and one "large" bracket. Each thruster bolts to a mounting flange on a bathtub-type small bracket. The small brackets bolt to the large bracket, which in turn bolts directly to the spacecraft upper deck. The +Y and –Y thruster configurations are mirror images of each other. During the spacecraft acoustic testing, a mass mockup of the thruster was used at each mounting location. Figure 4 shows the top deck configuration with the thruster brackets.

The thruster bracket is built up from T800/EX1515 composite laminate flat stock. The flat stock is bonded together using angle-clips to form the bracket. Figure 5 shows a detail of the MAP upper deck thruster bracket. The mounting faces of the bracket, which are labeled in the figure, are .072" thick while the remaining faces of the large and small brackets are .036" thick.

The map top deck is an aluminum honeycomb sandwich construction that is 5/8" thick with 0.015" M46J/934 facesheets. The deck is hexagonal in shape and measures approximately 94" across opposite points of the hexagon. There is a central hexagonal cutout in the deck where the deck attaches to the central "Hex-Hub" which is the primary load carrying structure for the spacecraft. The central cutout measures approximately 36" across opposite points. The top deck is supported at the central cutout by bolting to an inner support ring at the top of the Hex-Hub. The deck is also supported at the outer corners with Gr/Ep struts which run to the base of the Hex-Hub and to the lower deck. The remainder of the deck surface is unsupported. The features of the top deck can be seen in Figure 4.

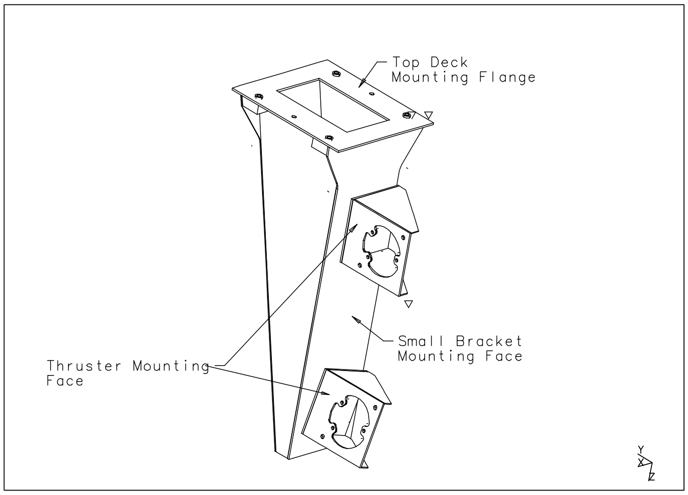


Figure 5. Detail of Upper Deck Thruster Bracke

ANALYSIS OF HIGH THRUSTER RESPONSE

After review of the acoustic test data showed the high response at the upper deck thruster locations, the spacecraft math model was used to determine the exact cause of the high responses. In order to do this, correlated models of the spacecraft bus and thruster bracket were required. A fairly detailed finite element model of the bracket had been developed for performing stress analysis but this model had never been correlated for use as a dynamics model. Offline sine-sweep testing of one of the flight thruster bracket was used to develop a correlated thruster bracket math model.

A modal survey was performed on the spacecraft bus with the +Y flight thruster bracket in place. The purpose of the modal survey test was to understand the interaction between the spacecraft top deck and the thruster bracket in order to determine the cause of the high acceleration response during acoustic testing. In order to accurately identify the mode shapes of the MAP top deck , a fairly fine mesh (5 x 5) of single axis accelerometers was used. These were mounted normal to the surface of the top deck in the region where the -Y thruster bracket was installed. In addition, triaxial accelerometers were attached to each of the mass mockups representing the thrusters as well as at the tip of the large thruster bracket. The details of the modal survey are provided in the

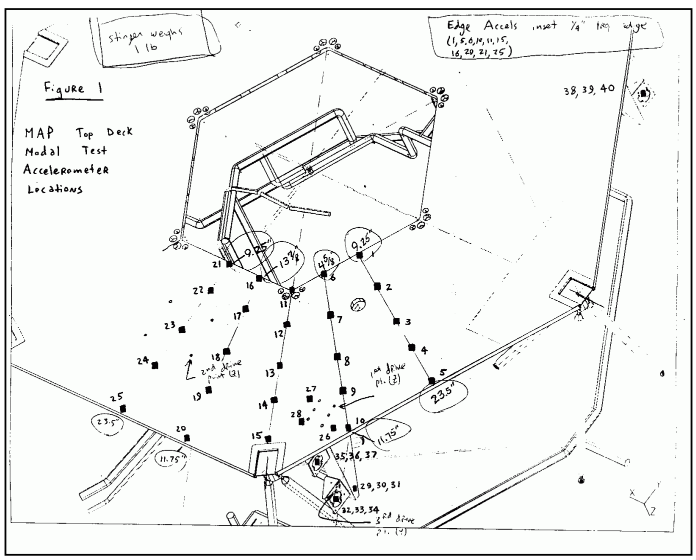


Figure 6. MAP S/C Modal Survey Accelerometer Locations

"MAP Spacecraft Top Deck Modal Test Plan, Rev A.", Perry Wagner/Code 542, dated November 10, 1998. Figure 6 shows the accelerometer locations used to calculate mode shapes from the modal survey data.

A math model of the modal survey test configuration was developed by coupling the correlated thruster bracket with a model of the MAP spacecraft. To match the test configuration, the MAP instrument and solar arrays were removed from the spacecraft model. This analytical model was then used to extract normal modes and frequency response functions (FRF) to compare with the test data.

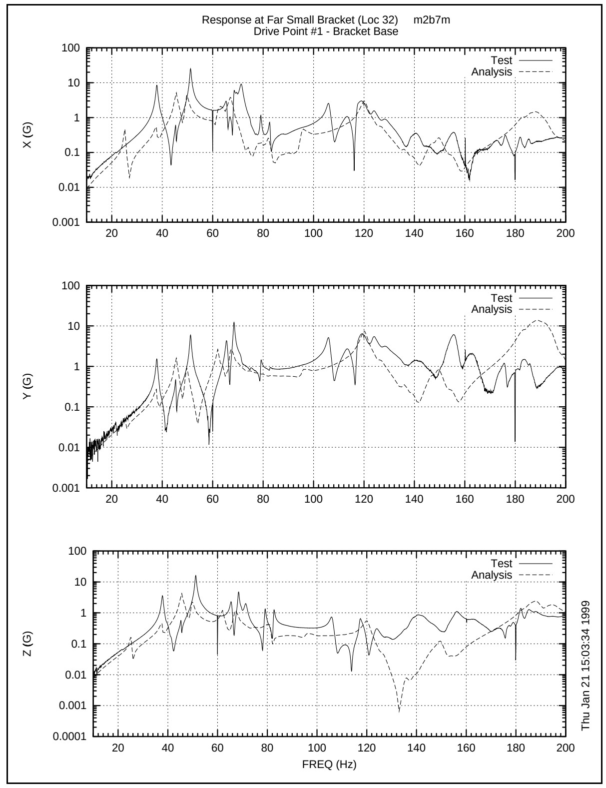


Figure 7. FRF Comparison (Test vs Analysis)

Figure 7 shows a comparison between FRF data measured from the modal survey and the same data derived from analysis. The data in Figure 7 represents the FRF for a drive point normal the top deck at one of the thruster bracket mounting locations. The test data showed that there were several modes in the 120-200 Hz range which excited high lateral (X and Y) responses of the lower thruster locations on the top deck. Review of the FEM showed the same characteristics. While not providing an exact match for frequency or mode-shape, the FEM model did have several modes which matched the test results for producing high interaction between the top deck and the thruster locations. These analytical modes occurred in the same frequency range as the modal survey test data, which was between 120 – 160 Hz. Based on these results, it was determined that the spacecraft FEM had sufficient accuracy to represent the modes contributing to the high thruster response. Figure 8 shows a comparison between one of the modes shapes identified as contributing to the high thruster bracket response and the corresponding mode shape

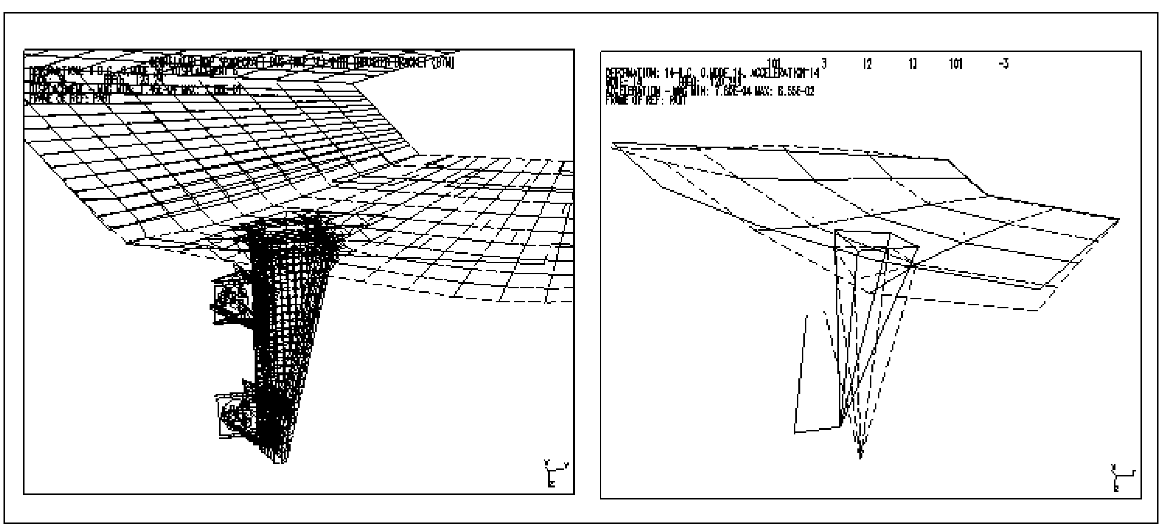


Figure 8. Mode Shape Comparison – Analytical (Left) vs Test (Right)

derived from the modal survey data. Both modes show a deflection of the deck edge coupled with local deformation of the small brackets to which the thrusters are mounted.

As an additional check of the validity of the math model to replicate the acceleration response measured during acoustic testing, a simulated acoustic analysis was performed. The acoustic input was simulated as a random analysis using a pressure field applied to the top deck based on the acoustic spectrum from the test.

Figure 9 shows the comparison between the measured test data from the acoustic test and the analytical simulation. The good correlation in the X and Y response directions showed that the peak responses measured during test could be reasonably predicted by this analysis procedure. The Z response direction did not show the same high degree of correlation as the other axes. However, because the measured PSD response on the Z direction below 200 Hz was significantly lower than the other response directions, it was felt that the math model and loading conditions had sufficient fidelity to be used to define the damping treatments necessary to reduce the high thruster response to acoustic input.

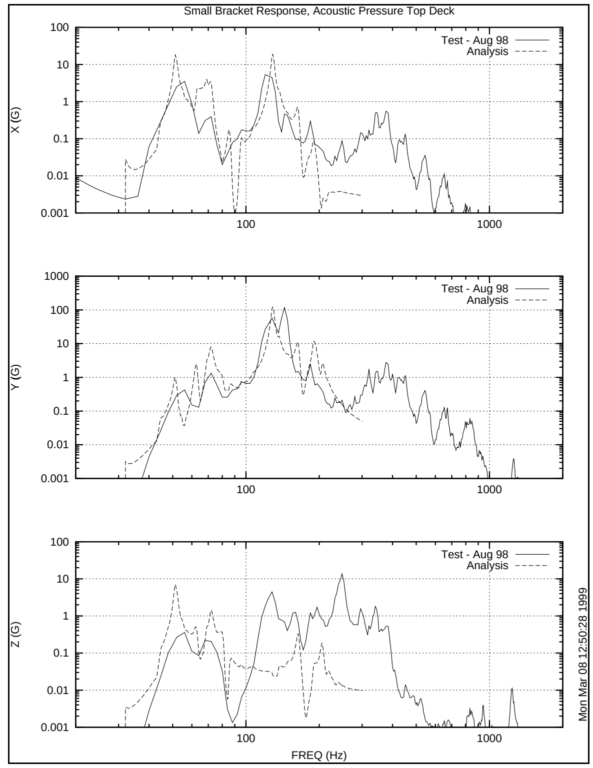


Figure 9. Acoustic Response Comparison (Test vs Analysis)

DISCUSSION OF SELECTED DAMPING TREATMENTS

Two damping treatments were selected for use on the MAP spacecraft to address the high acceleration response measured at the upper deck thruster mounting locations. Both types make use of a visco-elastic material (VEM) with a constraint layer. As discussed in the previous section, the mode shapes that had been identified as driving the thruster response were a combination of local bracket modes with deck modes. Therefore, damping treatments were applied to both the MAP top deck and to the thruster bracket directly.

The damping treatment applied to the thruster bracket is a .004” layer of 3M Scotchdamp ISD-242 with either a .072” or .036” Gr/Ep constraining layerto match the laminate thickness of the particular bracket face to which the damping treatment is applied. Figure 10 shows the locations on the thruster bracket where the scotchdamp has been applied to the flight thruster brackets. The selection of the Scotchdamp was based on work being done for the EOS-PM program in which Scotchdamp was being applied to the composite spacecraft bus to reduce acoustic response. Analysis was performed to determine where on the bracket the Scotchdamp should be located to provide the greatest damping for the modes of interest. This was done based on review of the modeshapes and targeting locations on the bracket that had the largest modal deflections. In order to determine the optimum thickness of the scotchdamp layer, a sensitivity analysis was performed to determine the strain energy in the scotchdamp as a function of VEM thickness.

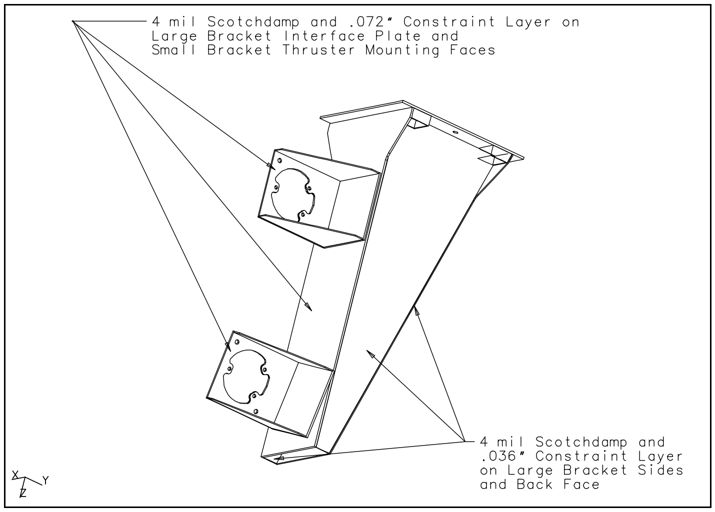


Figure 10. Damping Treatment Applied to Thruster Bracket

The damping treatment selected for the top deck consists of a .4" layer of Lockheed-Martin SMRD 100F-90C with a honeycomb sandwich constraining layer. Figure 11 shows the dimensions of the SMRD damping strips used for this application. SMRD was selected for this application based on

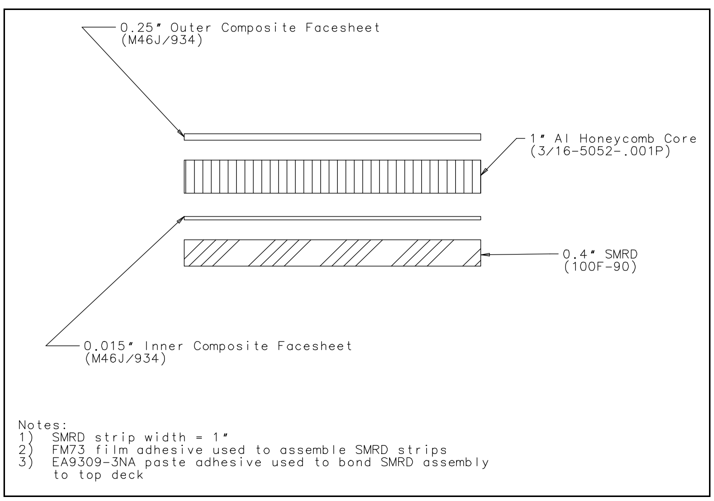


Figure 11. SMRD Damping Strip Configuration

its use at Goddard on the XTE program. The initial sizing of the SMRD strips was performed based on the information provided in References (a) and (b.) A sensitivity analysis was performed to provide additional optimization of the SMRD and constraint layer. The sensitivity analysis tracked the amount of strain energy in a given mode based on changes in the thickness of the SMRD and the constraint layer.

The SMRD assembly was cut into strips with a 1" width and bonded to the edges of the top deck in the bays where the thruster brackets are mounted. Review of target modes showed that the largest deflection occurred at the deck edges. Scotchdamp with a constraining layer was also applied to

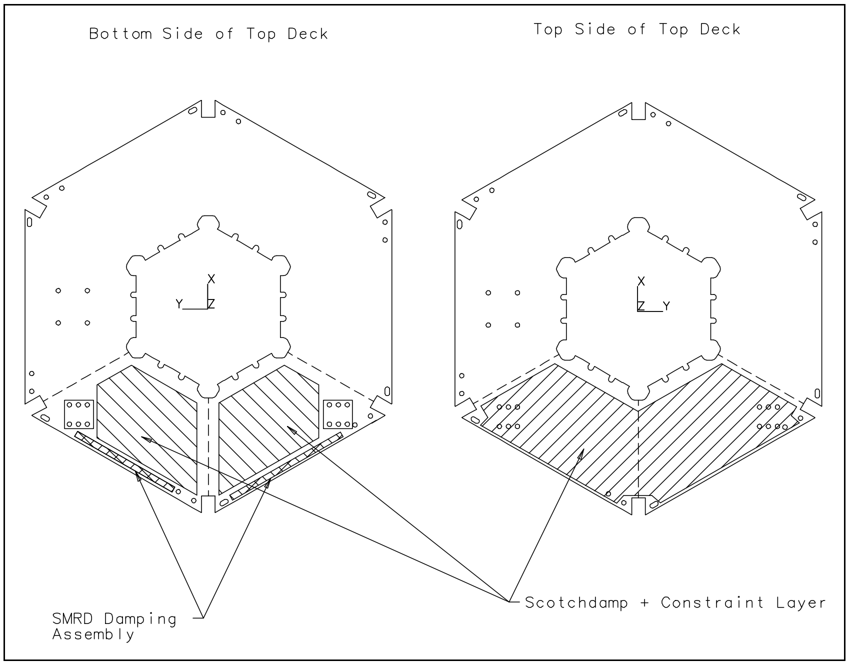


Figure 12. Top Deck Damping Treatments

both sides of the MAP deck in Bays 4 & 5 to provide additional damping of the deck. The overall damping treatments applied to the top deck are shown in Figure 12.

PREDICTIONS OF RESPONSE REDUCTIONS FROM DAMPING TREATMENTS

In order to estimate the damping that would be obtained using the above damping treatments, the effect of the SMRD and the scotchdamp was modeled analytically. This was done using the approach outlined in Reference (c) which uses NASTRAN solid elements (HEXA and PENTA) to model the VEM layer and thin shell elements (QUAD4) to model the constraint layer. The normal modes solution is run and the percent strain energy in each mode is recovered. The modal damping associated with the VEM for each mode is then calculated using the following equation taken from Reference (c):

$$\zeta_v = .5 * \eta_v * \sqrt{G_v(f) / G_{vref}} * \left[SE_{vem} / SE_{total} \right] \quad (1)$$

where

ζ_v	=	Ratio of Critical Damping (C/C_0) due to VEM
η_v	=	VEM damping loss factor at the specific mode of interest. This quantity is frequency and temperature dependent.
$G_v(f)$	=	Actual shear modulus of the VEM at the specific mode of interest.
G_{vref}	=	VEM shear modulus at the frequency at which the damping treatment is being targeted. This is the shear modulus input to NASTRAN for the normal modes analysis
SE_{vem}/SE_{total}	=	Ratio of strain energy in the VEM to the strain energy at the specific mode of interest

The VEM damping calculated from Equation (1) is then added to the nominal modal damping of the structure to arrive at an overall damping value. The nominal modal damping is the damping that exists for the structure prior to the application of the damping treatments. This can either be an estimated or measured value. The overall modal damping, VEM + nominal, can then be used in subsequent dynamic analyses to predict the acoustic response of the structure with the damping treatments applied.

The analytical technique for predicting constraint layer damping was verified by testing performed on beam coupons that had a layer of Scotchdamp sandwiched between two facesheets. The beam coupons were approximately 1” wide with a length of 6”. Different thicknesses of the Scotchdamp as well different thicknesses and types of facesheets (composite and aluminum) were tested. The testing was done using random vibration input on a shaker table. The beam coupons were held cantilevered and the tip response was measured with an accelerometer at the free end. This data was then compared to the analytical predictions of the test. The results showed that the analysis technique provided good correlation to test data and produced results that were slightly conservative (i.e. underpredicted the actual damping in the test article). No testing was performed on the SRMD configurations.

Once the analytical technique for estimating constraint layer damping had been verified, this technique was applied to the MAP spacecraft to predict the estimated reduction in thruster response due to the proposed damping treatments. This analysis was performed in two parts. The first part estimated the reduction in response due to the application of the Scotchdamp to the bracket only. The second part estimated the combined effect of the Scotchdamp on the thruster bracket plus the additional damping effect of the SMRD strips on the top deck. The Scotchdamp on the top deck was not included in this analysis because of the complexity of adding the required elements to the model. Table 1 gives the VEM material properties that were used in this analysis. The curves showing the damping loss factor and shear modulus as a function of frequency and temperature for the Scotchdamp and SMRD are provided in Appendix B. A nominal damping value of 1.6% was used for this analysis based on the data from the initial spacecraft acoustic test.

Table 1. VEM Material Properties used to Calculate Damping

	Properties @ t=70° F and f=140 Hz	
Description	**Damping Loss Factor** η_v	**Shear Modulus** G_{vref} **(psi)**
3M Scotchdamp ISD-242 (1)	1.0	1050
Lockheed-Martin SMRD 100F-90C (2)	1.0	4000

Notes:
(1) Material data from nomograph supplied by 3M
(2) Material data from nomograph provided in Reference (b)

Figure 13 shows the predicted acoustic response with the addition of just the Scotchdamp on the thruster bracket as well as the response due to the combined effect of the Scotchdamp and SMRD damping treatments. The analysis predicts a9 dB reduction in peak response due to the Scotchdamp on the thruster bracket and a 17 dB reduction due to the combined effects of the Scotchdamp and SMRD. While the predicted reductions in response due to the damping

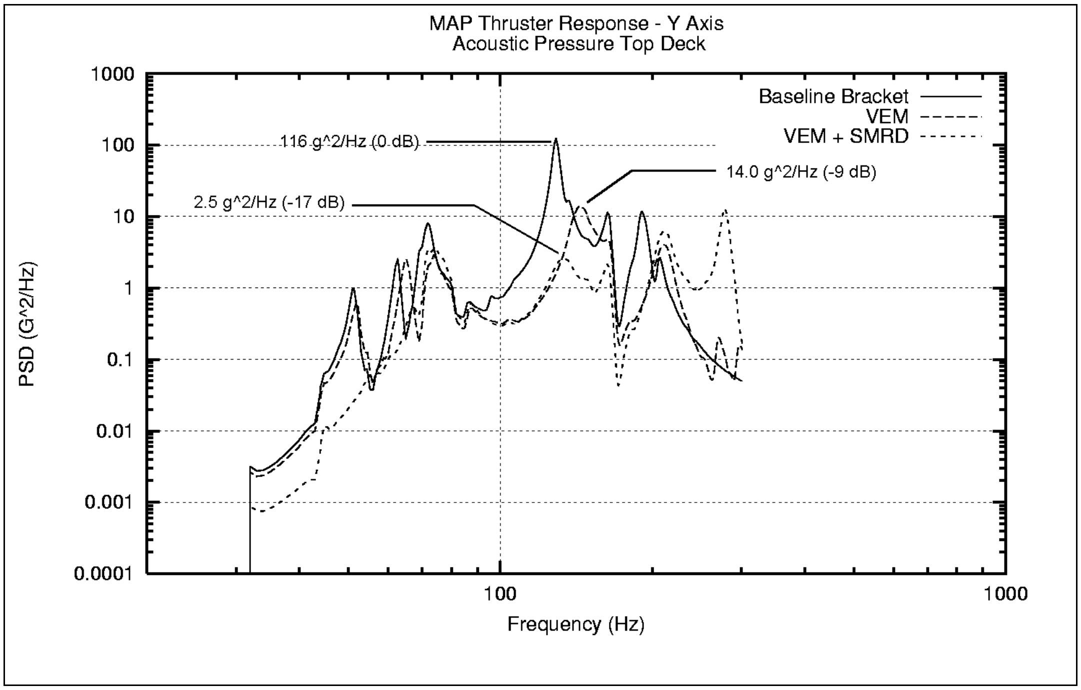


Figure 13. Analytical Prediction of Thruster Response Reduction due to Damping Treatments

treatments are significant, the input levels to the thruster still exceed the manufacturers qualification levels of 0.2 g2/Hz and 20 G_{rms} overall. This was not considered a problem for the actual flight configuration because of other factors that would serve to reduce the acoustic response which were not accounted for in the above analysis. These include the following:

1. Blanketing and harnesses. Test data from other programs have shown that blankets and harnesses can reduce acoustic response by as much as10 dB in the 100-400 Hz range.
2. Rubber shims added to the interface between the large and small brackets. These were shown to provide from 3-9 dB reduction based on offline testing of the thruster bracket.
3. Scotchdamp applied to the top deck. Although not included in the analysis, this was expected to provide at least an additional 3 dB reduction based on test data from TRW for the EOS-PM program.

It was felt that these additional reductions in acoustic response would be sufficient to bring the acceleration response at the thruster locations to within the thruster qualification levels.

“INTERMEDIATE” OBSERVATORY LEVEL ACOUSTIC TEST – JULY, 1999

An acoustic test of the MAP observatory was performed on July 1 and 2, 1999. The purpose of this test was to verify that the damping treatments added to the spacecraft were sufficient to reduce the thruster response to levels that were enveloped by the qualification testing of the thrusters. The details of the test are given in the “MAP Spacecraft and Solar Array Deployment System (With Added Top Deck Damping Material) Acoustic Test Plan”, Jim Loughlin/Code 542, dated June 14, 1999. The accelerometer locations on the top deck and thruster bracket were placed as close as possible to the locations from the first spacecraft acoustic test. The acoustic test was called "Intermediate" because it had been added to the test flow after acoustic testing of the spacecraft had been completed but prior to acoustic testing at the observatory level. Therefore, this acoustic test was occurring after a significant portion of the flight components had been integrated to the spacecraft bus. The test configuration consisted of the flight MAP spacecraft bus with most of the flight electronics, propulsion system including the flight thrusters, and full electronic harnesses with the exception of the instrument harness. In addition, most of the spacecraft thermal blankets were in place using either flight or test blankets. Every effort was made to get the spacecraft as close as possible to the actual flight configuration to obtain data that would accurately represent the acoustic responses that would occur during launch. As before, the ETU solar arrays and deployment system were installed however, for this test neither the flight instrument or instrument simulator were used.

The proto-flight acoustic test spectrum to which the test article was exposed is provided in Appendix C. These levels have been reduced slightly from the original proto-flight test levels used for the initial spacecraft acoustic test. The reductions occur in the 1/3-octave bands from 100-200 Hz and from 300-500 Hz. After the results of the first acoustic test, Boeing had been asked to review flight data for the Delta II launch vehicle to determine if reductions in the expected flight environment were possible. The levels used for this acoustic test were the result of that review. Figure 14 shows a comparison between the acoustic levels from each of the acoustic tests.

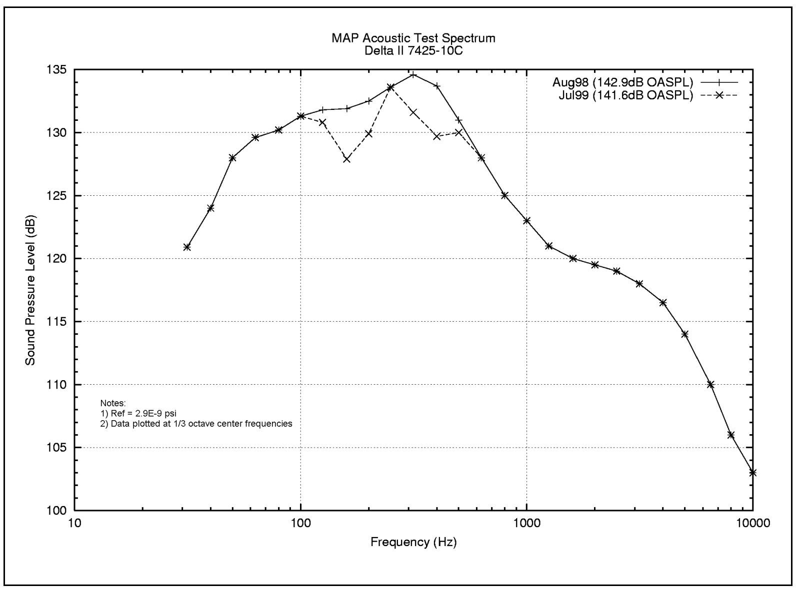


Figure 14. Comparison of Acoustic Test Spectrums

Since the spacecraft was configured with a significant number of flight components including the flight thrusters, the test was started at a lower level of input to protect these components from damage. The test plan called for an initial acoustic run at –18dB as referenced to the acoustic spectrum in Appendix C and then for subsequent runs at –12 and –6 dB. The highest acoustic input planned for this test was –6 dB. The proto-flight responses during observatory testing would be extrapolated from this data. The duration of each test run would be 30 seconds. The PSD response at the thruster locations and other selected points on the spacecraft would be reviewed after each run to determine if it was safe to proceed to the next level. The actual test was conducted to a maximum level of –7 dB from the full proto-flight acoustic spectrum so as to limit the response of thrusters located on the bottom deck of the spacecraft until the thruster manufacturer could review the test data.

When the acceleration PSD data from the –7 dB acoustic test was extrapolated to full proto-flight levels, it showed that the responses measured at the upper deck thruster locations had been significantly reduced from prior acoustic testing. The response data showed a peak PSD level of 4.5 g^2/Hz with an overall level of 10.36 G_{rms}. Figure 15 shows the PSD level measured at the

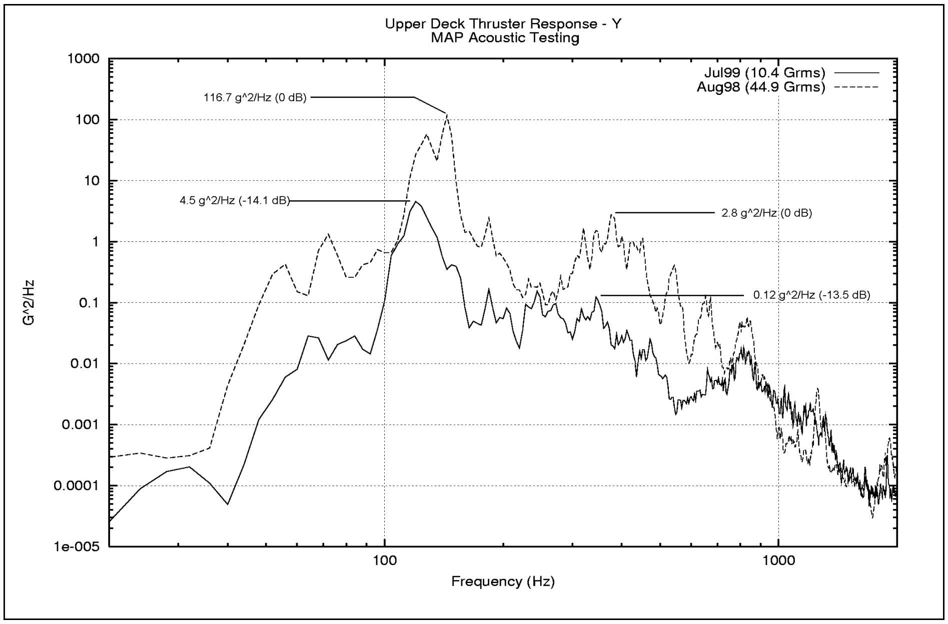


Figure 15. Thruster Response to Acoustic Excitation Before (Aug98) and After (Jul99) Damping Treatments

lower thruster location on the –Y thruster bracket as compared with the same location from the first MAP acoustic test. For comparison, the –7 dB test data from this acoustic test (Jul99) has been scaled up to full level. The data has not been corrected for differences in the acoustic input spectrum. The PSD acceleration data from this acoustic test which corresponds to the 9 top deck channels which were acquired during the first acoustic test is provided in Appendix C.

The acoustic test data shows that the modifications made to the thruster bracket and to the spacecraft have reduced the overall level well below the thruster requirement of 20 G_{rms} and most of the measured response is below the 0.2 g^2/Hz level as well. There is still a significant peak at 120 Hz but it has been reduced by 14 dB from the previous acoustic test. The thruster manufacturer reviewed the acoustic test data and determined that the current flight environment is less severe than random vibration levels to which the thruster had been previously qualified. This was based on a review of the thruster stress margins given the new input levels and the fact that the thruster resonances occur above 300 Hz. Therefore, the thruster input levels have been reduced sufficiently to show that the thrusters have been adequately qualified for the MAP flight environment based on previous qualification testing.

COMPARISON OF DAMPING PREDICTIONS WITH TEST DATA

Figure 16 shows a comparison of the test data from the "Intermediate" acoustic test of the MAP observatory with the analytical predictions of the expected response. The analytical predictions account for the damping due to the Scotchdamp applied to the thruster bracket and the SMRD strips applied to the edges of the top deck in bays 4 & 5. The analytical prediction is within 3 dB

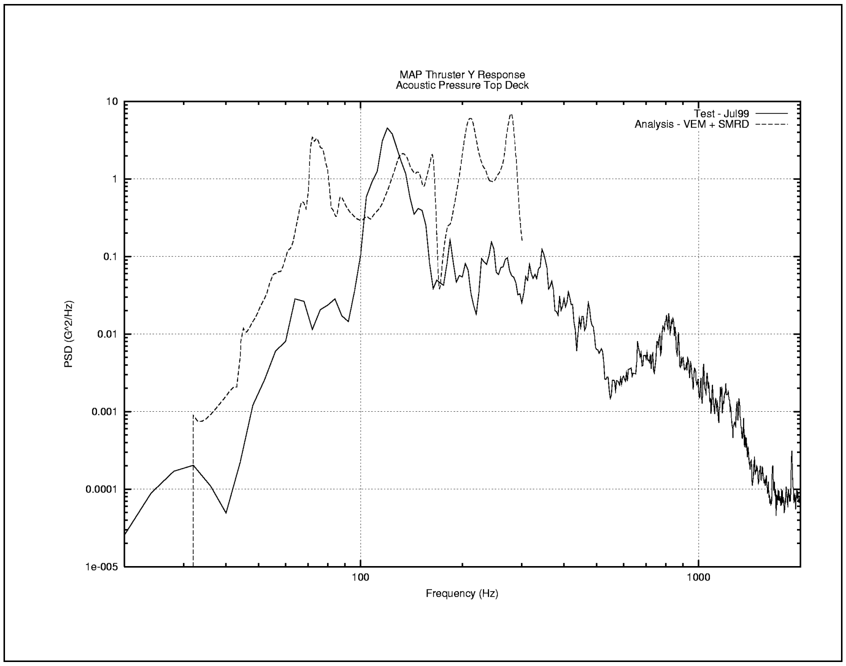


Figure 16. Comparison of Acoustic Test Resultsvs Analytical Prediction of Thruster Response

of the peak test response at 120 Hz but overpredicts the response above and below that frequency. While the analytical results initially appear promising, the fact that the peak test response is underpredicted is a bit troublesome. The analysis does not account for several factors that were originally thought to contribute to reduction in acoustic response (page 11) as well as the fact that the analysis does not include the reduction in acoustic input shown in Figure 14. Therefore, one would expect the analysis results to overpredict the test results across all frequencies. There are a number of possible explanations for why this is not the case. They are as follows:

1. The NASTRAN model may not have sufficient resolution required to accurately predict damping for the complicatedmodeshapes which drive the high acoustic response.
2. The analysis technique for predicting modal damping was not verified with test data for SMRD. The SMRD strips may have been less effective in damping the thruster modes than predicted.
3. Low level (-7 dB) acoustic data was scaled to full level to estimate damping reductions. Significant damping effects may not be present until structure is exposed to higher levels of input.

4. The expected acoustic reductions may not be cumulative. Effects that independently produce a certain reduction in acoustic response may not linearly add when applied together.
5. Expected acoustic reductions may not be directly applicable to the high response at the thruster locations. For instance, the addition of blanketing and harnesses may not have significantly effected the local bracket response.

The analytical technique for calculating modal damping based on strain energy is really the only tool available that can be used to optimize the configuration and location of constrained layer damping treatments to reduce dynamic response. The beam coupon testing indicated that the technique showed good correlation for simple structures with well-defined modes and fairly simple dynamic inputs. The poor correlation between the analytical results and the acoustic test data for the MAP spacecraft seems to indicate that this technique may not be as effective in predicting the response magnitude of complicated structures with a large number of modes and complex loading conditions (i.e. acoustic input).

CONCLUSION

The use of constrained layer damping on the MAP spacecraft was successful in reducing the acoustic response at the upper deck thruster locations to acceptable levels. The reductions were sufficient to show that the thrusters had been adequately qualified for the MAP acoustic environment based on previous thruster qualification testing. Data from acoustic testing of the MAP spacecraft with the damping treatments in place was used to make this assessment. An analysis technique that calculated modal damping based on strain energy was used to define the configuration of the damping treatments. This analysis technique was straightforward to implement and was used with existing NASTRAN models of the MAP spacecraft. However, comparison of analytical predictions of acoustic response with test data showed that the analysis underpredicted the peak acoustic test response. The modal strain energy approach is a good tool for optimizing the use of constrained layer damping treatments but the technique may not be able to accurately predict the magnitude of dynamic response depending on the structure and the loading conditions. Therefore, predictions of dynamic response for structures with constrained layer damping should be verified by testing the structure under the expected loading conditions.

Scott Gordon

3 Enclosures:
Appendices A-C

w/o appendices:
540/Mr. E. Powers
540/Mr. S. Brodeur
540/Mr. M. Hagopian

cc:
542/Mr. J. Decker
542/Mr. F. Tahmahsebi
Swales/Mr. S. Hendricks
Swales/Mr. P. Wagner

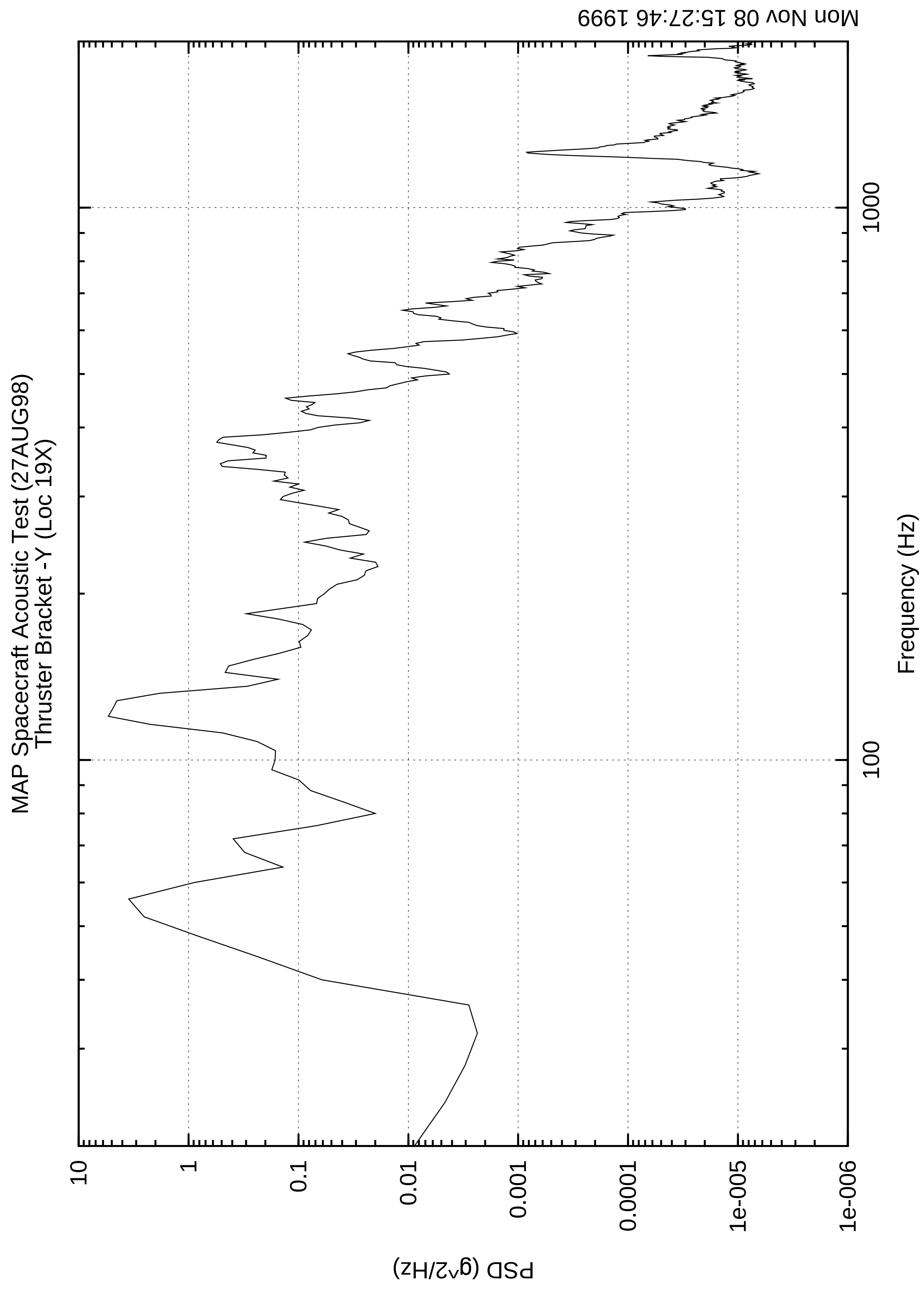
APPENDIX A
MAP Spacecraft Level Acoustic Test
August 1998

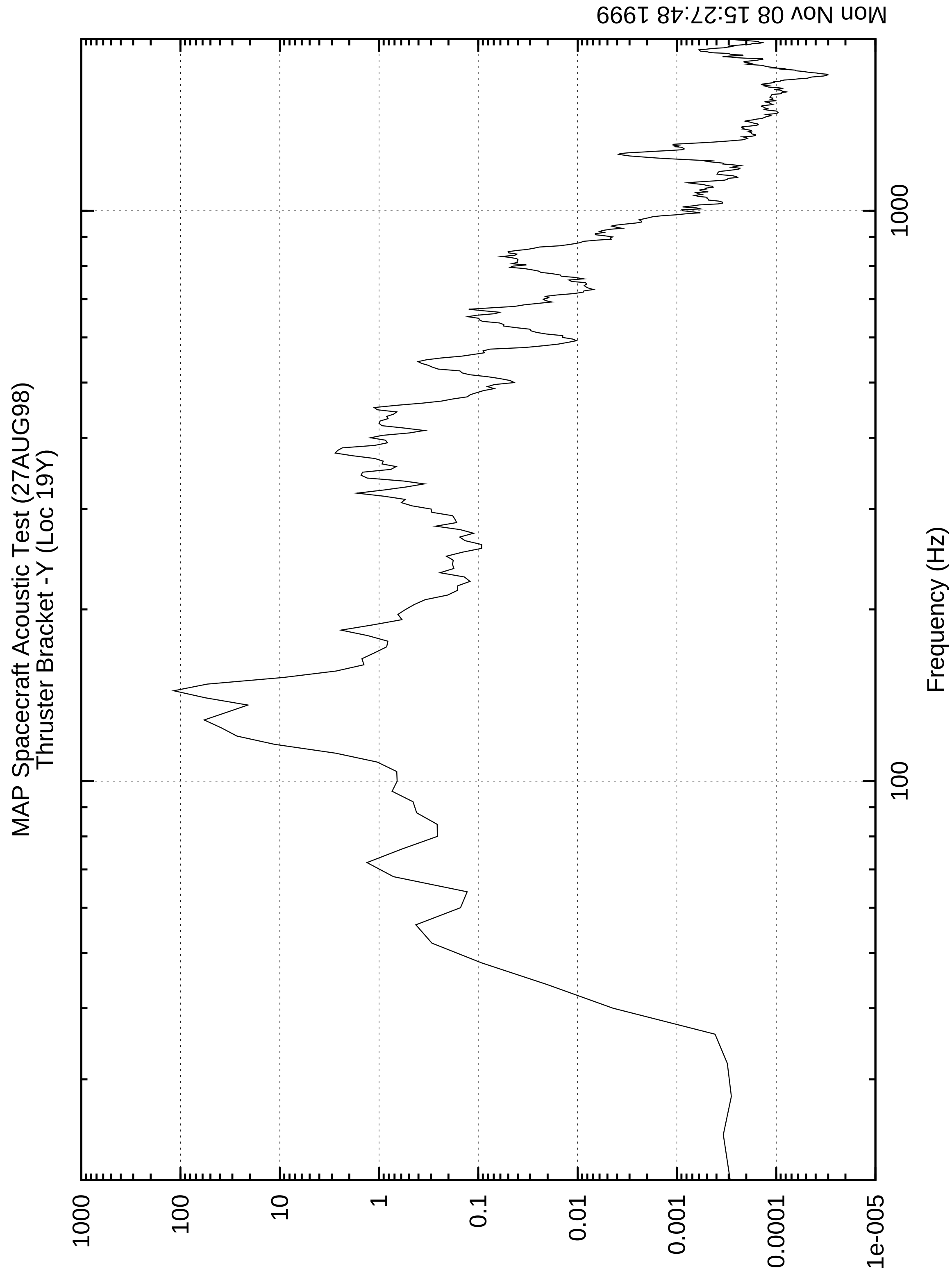
- Acoustic Test Levels
- Top Deck Accelerometer PSD Data

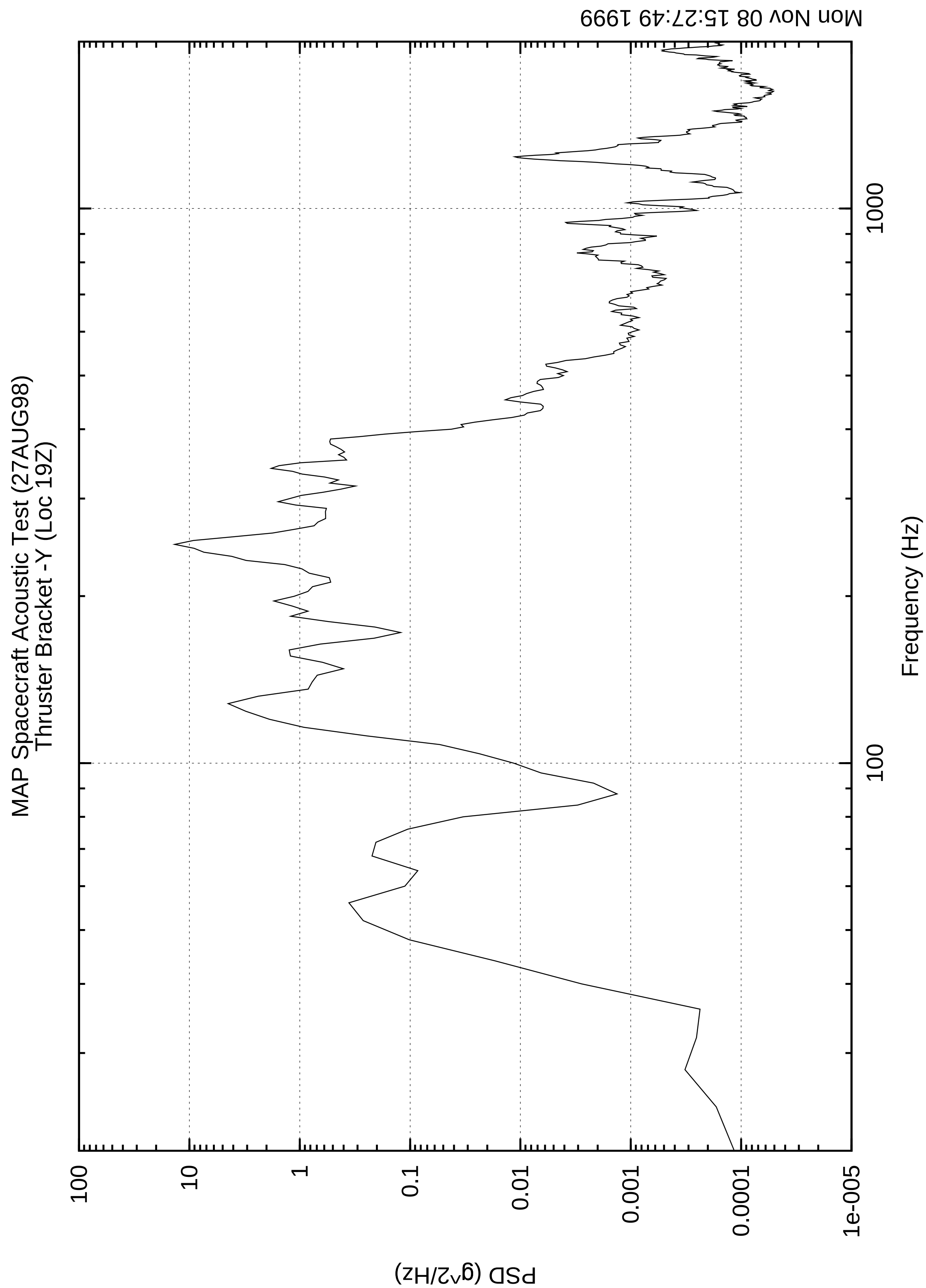
MAP Spacecraft Acoustic Test Levels

One-Third Octave Center Frequency (Hz)	Flight Level (dB)	Protoflight Level (dB)
31.5	117.9	120.9
40	121	124
50	125	128
63	126.6	129.6
80	127.2	130.2
100	128.3	131.3
125	128.8	131.8
160	128.9	131.9
200	129.5	132.5
250	130.6	133.6
315	131.6	134.6
400	130.7	133.7
500	128	131
630	125	128
800	122	125
1000	120	123
1250	118	121
1600	117	120
2000	116.5	119.5
2500	116	119
3150	115	118
4000	113.5	116.5
5000	111	114
6300	107	110
8000	103	106
10000	100	103
OASPL	139.9	142.9

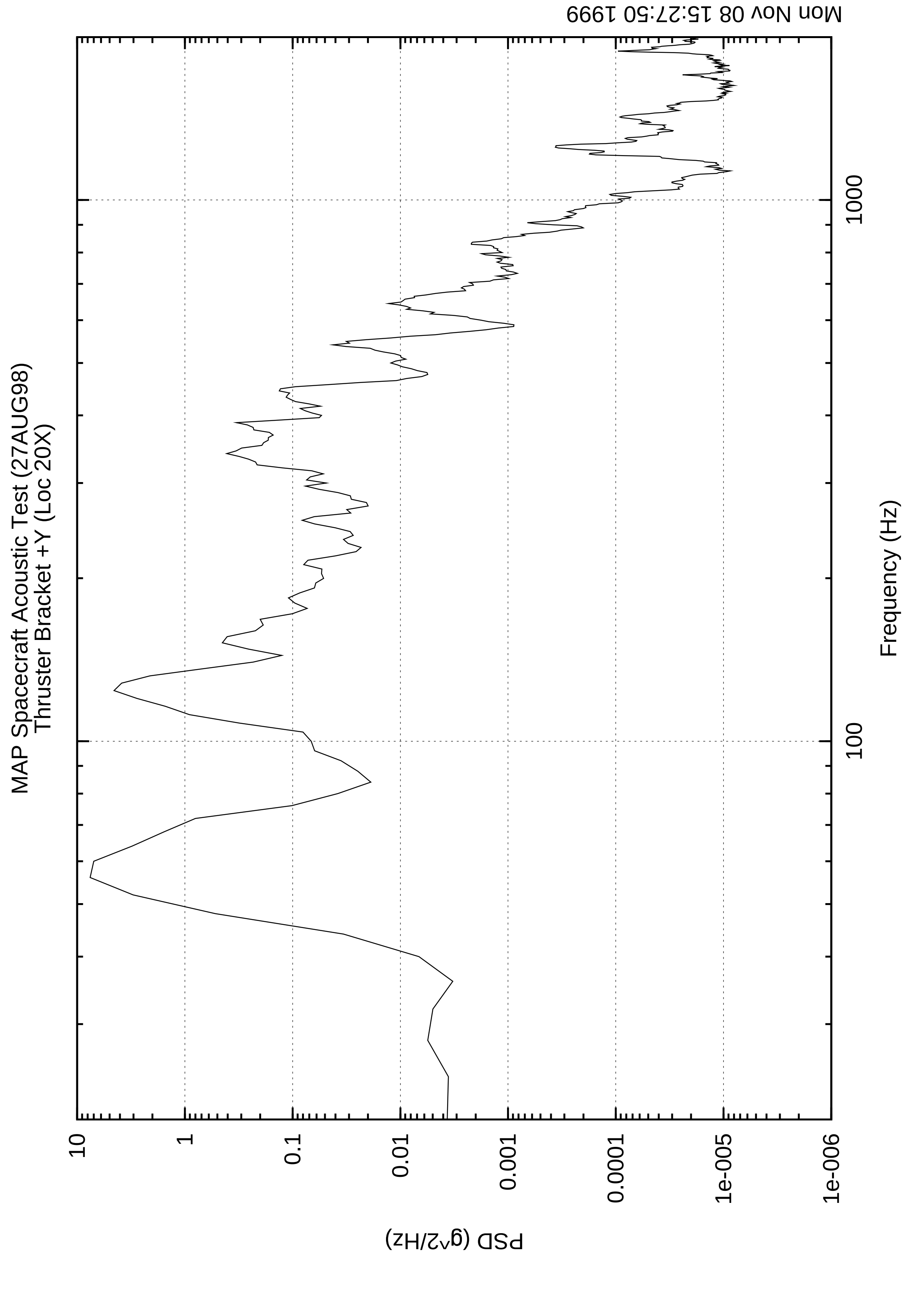
Acoustic test duration = 60 second

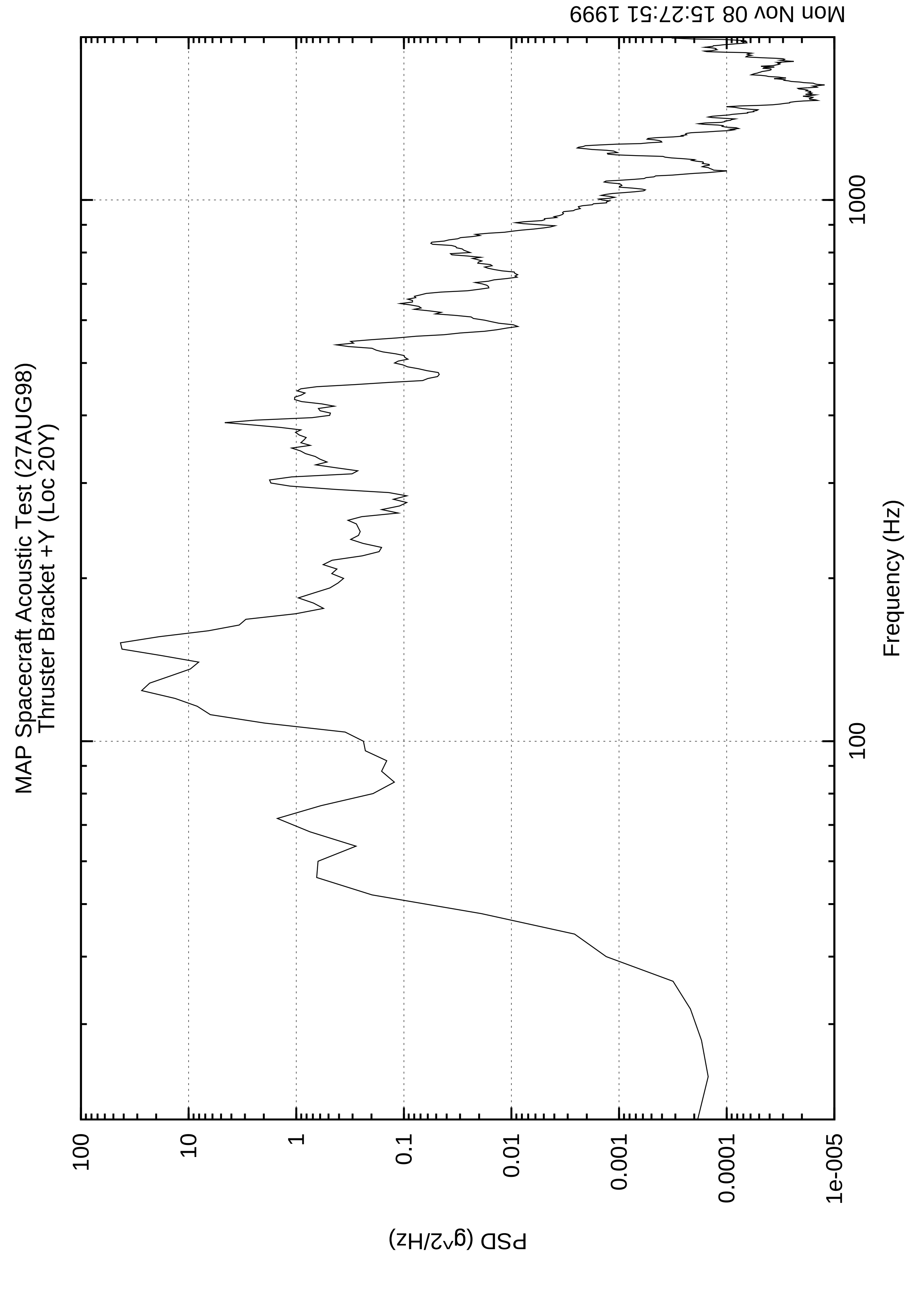

MAP Spacecraft Acoustic Test (27AUG98)
Thruster Bracket -Y (Loc 19X)
Mon Nov 08 15:27:46 1999
PSD (g^2/Hz)
10
1
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)

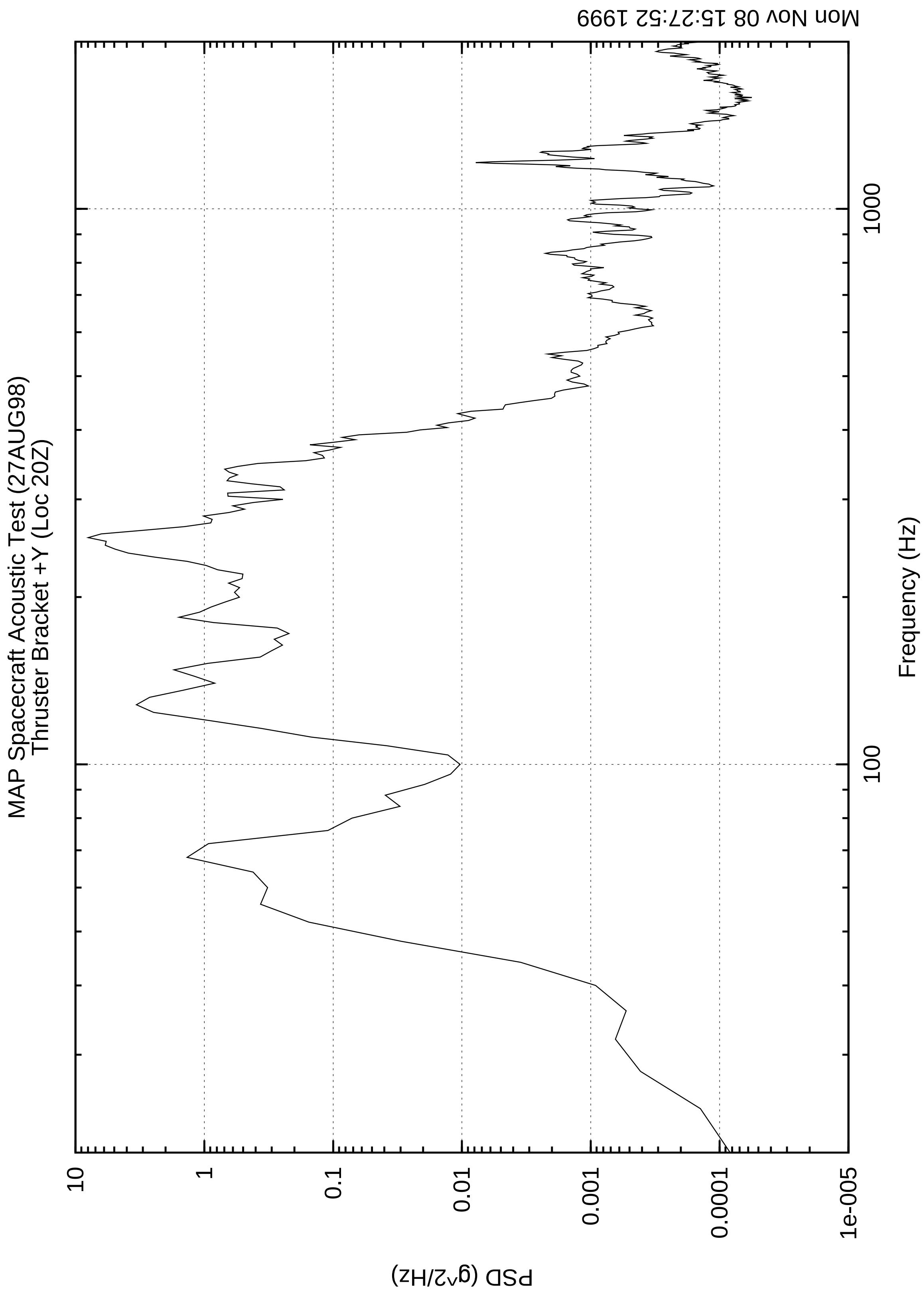

MAP Spacecraft Acoustic Test (27AUG98)
Thruster Bracket -Y (Loc 19Y)
Mon Nov 08 15:27:48 1999
PSD (g^2/Hz)
1000
100
10
1
0.1
0.01
0.001
0.0001
1e-005
Frequency (Hz)
100
1000

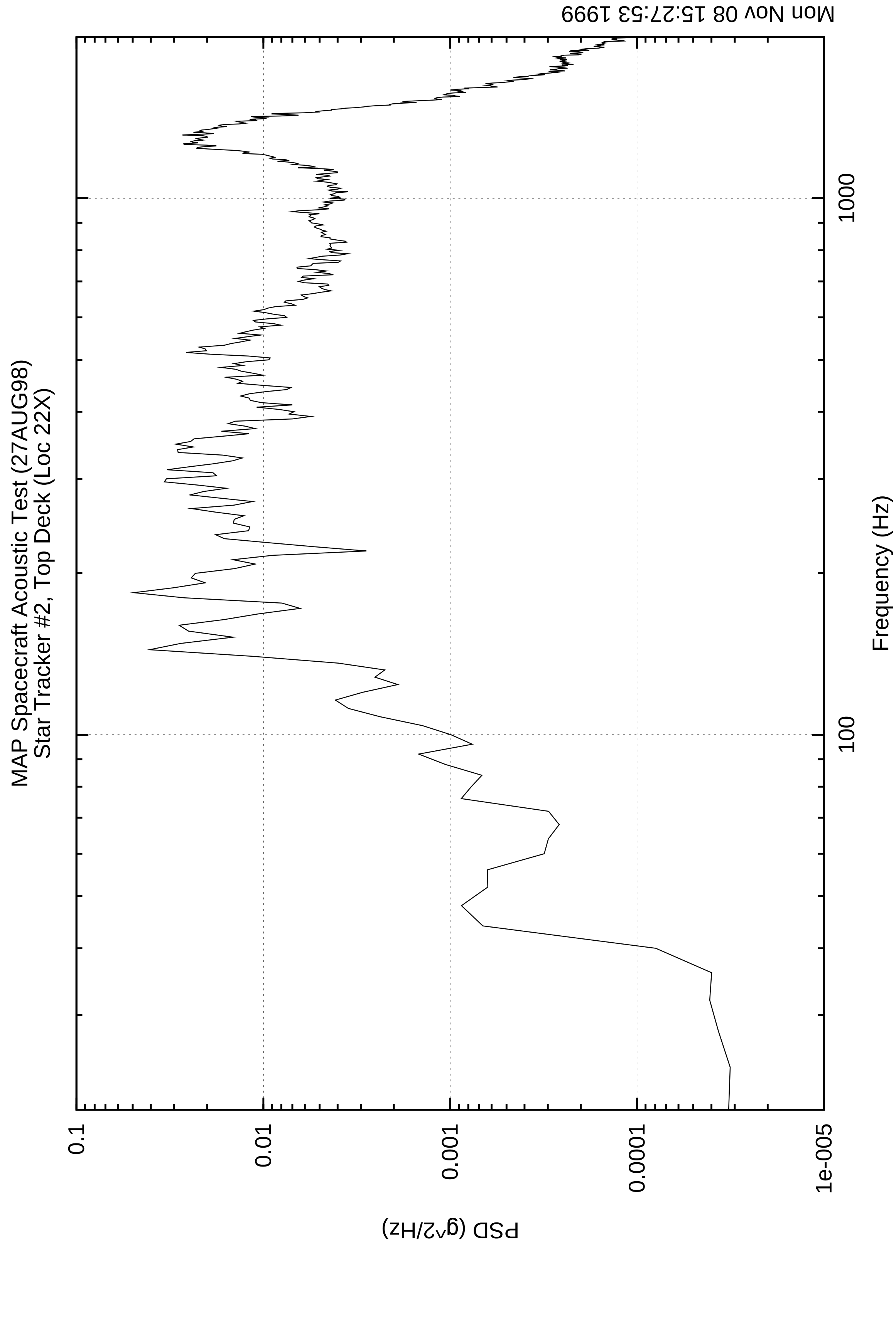


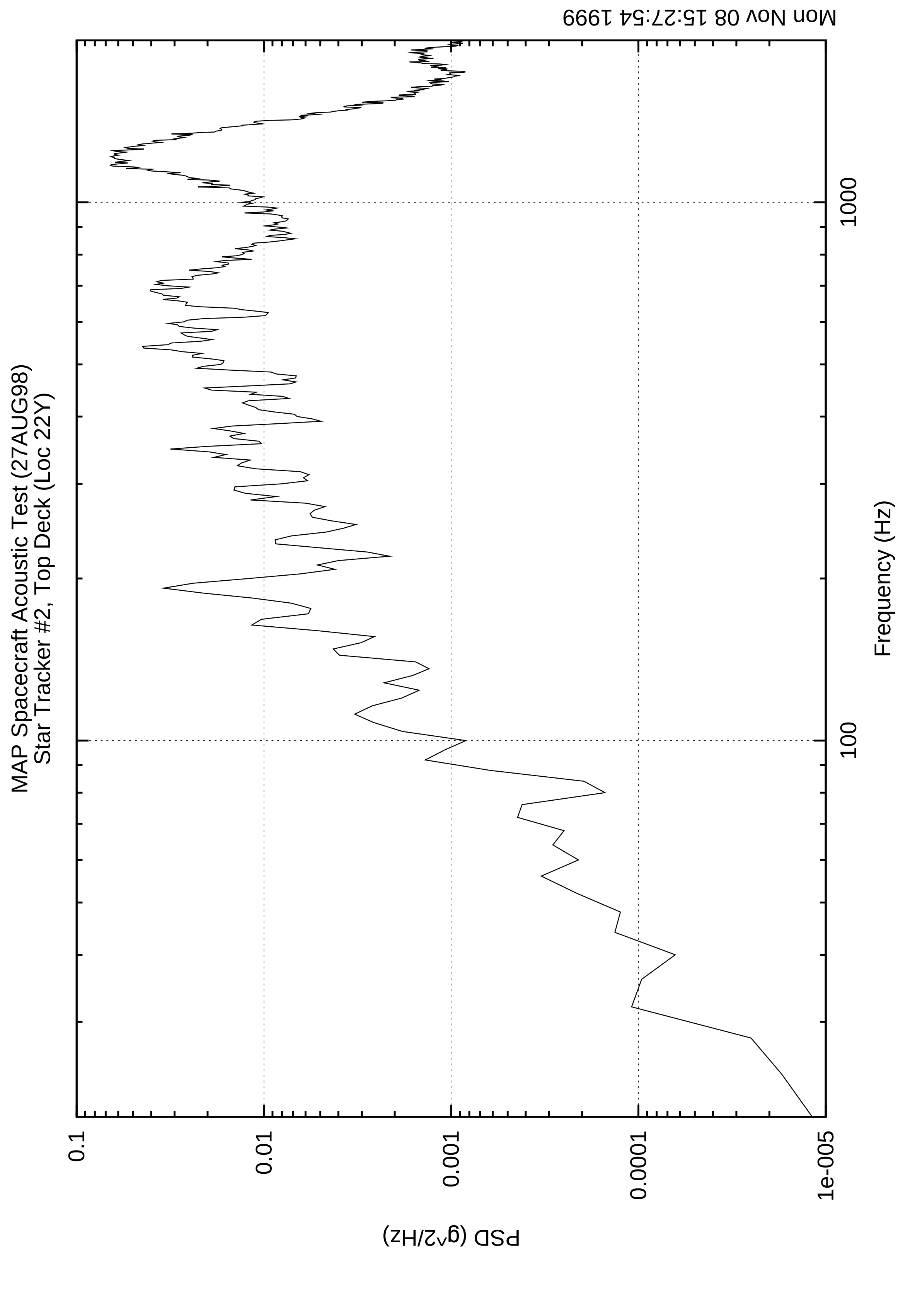
MAP Spacecraft Acoustic Test (27AUG98)
Thruster Bracket -Y (Loc 19Z)
Mon Nov 08 15:27:49 1999
PSD (g^2/Hz)
100
10
1
0.1
0.01
0.001
0.0001
1e-005
100
1000
Frequency (Hz)

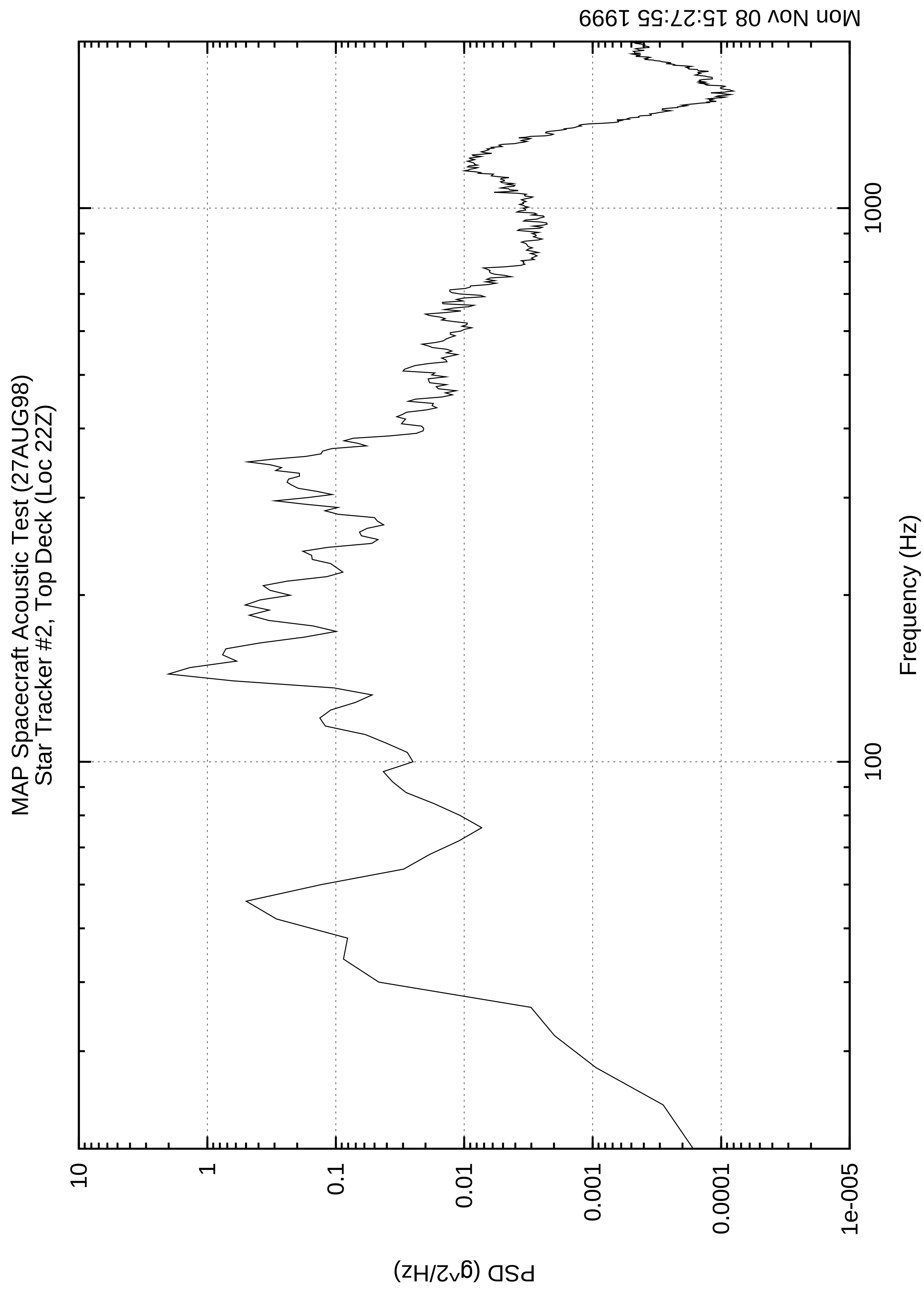

MAP Spacecraft Acoustic Test (27AUG98)
Thruster Bracket +Y (Loc 20X)
Mon Nov 08 15:27:50 1999
PSD (g^2/Hz)
10
1
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)


MAP Spacecraft Acoustic Test (27AUG98)
Thruster Bracket +Y (Loc 20Y)
Mon Nov 08 15:27:51 1999
PSD (g^2/Hz)
100
10
1
0.1
0.01
0.001
0.0001
1e-005
100
1000
Frequency (Hz)


MAP Spacecraft Acoustic Test (27AUG98)
Thruster Bracket +Y (Loc 20Z)
Mon Nov 08 15:27:52 1999
PSD (g^2/Hz)
Frequency (Hz)
10
1
0.1
0.01
0.001
0.0001
1e-005
100
1000


MAP Spacecraft Acoustic Test (27AUG98)
Star Tracker #2, Top Deck (Loc 22X)
Mon Nov 08 15:27:53 1999
PSD (g^2/Hz)
Frequency (Hz)
0.1
0.01
0.001
0.0001
1e-005
100
1000


MAP Spacecraft Acoustic Test (27AUG98)
Star Tracker #2, Top Deck (Loc 22Y)
Mon Nov 08 15:27:54 1999
PSD (g^2/Hz)
0.1
0.01
0.001
0.0001
1e-005
Frequency (Hz)
100
1000


MAP Spacecraft Acoustic Test (27AUG98)
Star Tracker #2, Top Deck (Loc 22Z)
Mon Nov 08 15:27:55 1999
PSD (g^2/Hz)
Frequency (Hz)
10
1
0.1
0.01
0.001
0.0001
1e-005
100
1000

APPENDIX B
Visco-Elastic Material Properties
Nomographs

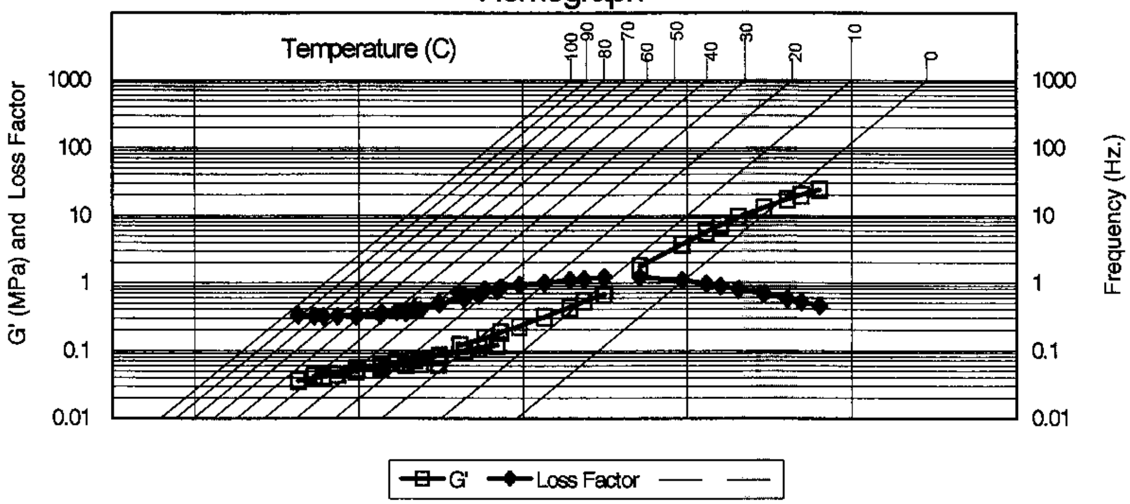
- 3M Scotchdamp ISD 242
- Lockheed-Martin SMRD 100F-90C

3M Scotchdamp ISD-242 Material Properties

3M

Scotchdamp **242F01, 242F02, 242F04**

242 Viscoelastic Damping Polymer
Nomograph



Nomograph

- The viscoelastic material damping properties are in the "reduced temperature format" nomograph. The Loss Factor and Storage Modulus are found for the 242 viscoelastic damping polymer by selecting the frequency desired and extending a horizontal line from that frequency until the temperature isotherm is intersected. Extend a vertical line from this first intersection point so that it intersects the Loss Factor and Storage Modulus curves. The Loss factor and Storage Modulus are found on the left hand scale by extending a line horizontally from these second intersection points.

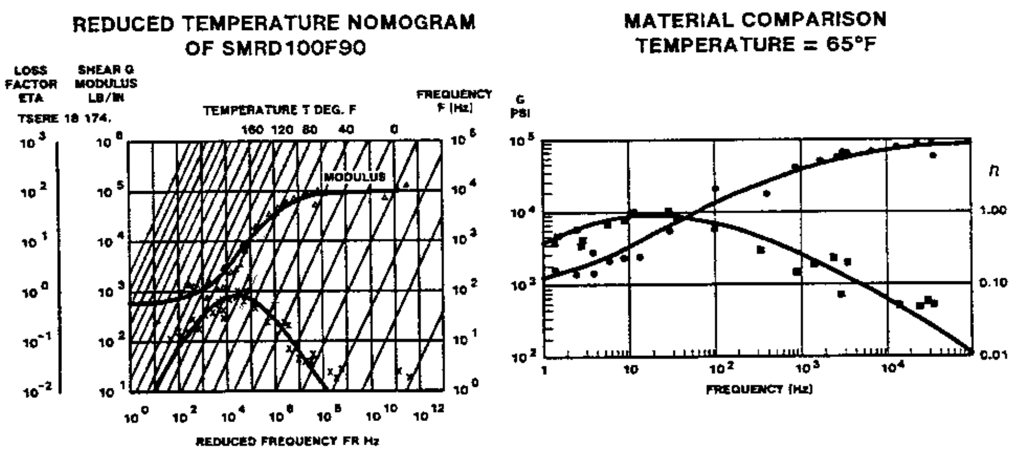
Outgassing

- Typical nominal total outgass material by GC/MS (Modified ASTM 4526)
- 242F01 - 0.8 ug/cm^2 (Hydrocarbons, Organic acids, Esters, Alcohols, Phenols, Siloxane)
- 242F02 - 1.0 ug/cm^2 (Hydrocarbons, Organic acids, Esters, Alcohols, Phenols, Siloxane)
- 242F04 - 5.0 ug/cm^2 (Hydrocarbons, Organic acids, Esters, Alcohols, Phenols, Siloxane)

Ionics

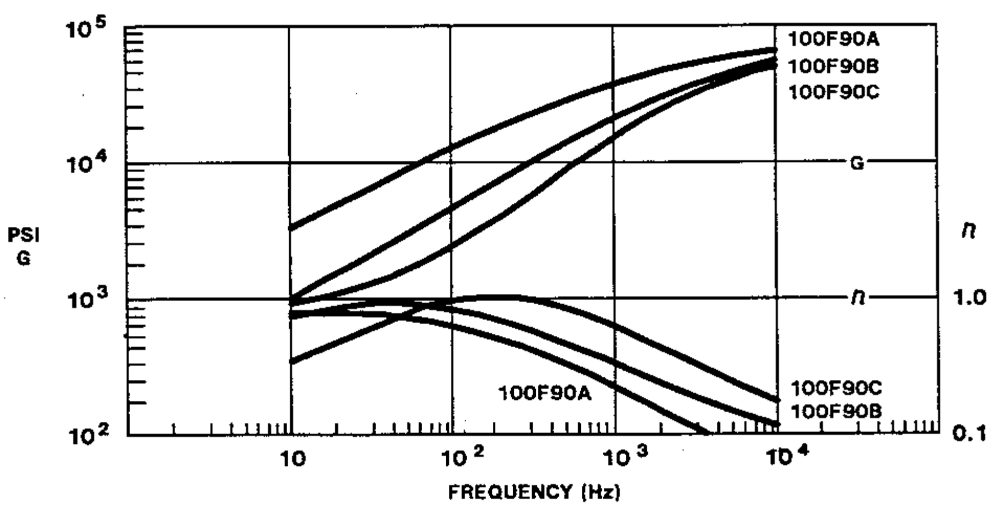
- Typical total ionics by Ion Chromatograph
- 242F01 - < 0.20 ug/cm^2 (Chloride, Nitrate, Sulfate)
- 242F02 - < 0.20 ug/cm^2 (Chloride, Nitrate, Sulfate)
- 242F04 - < 0.20 ug/cm^2 (Chloride, Nitrate, Sulfate)

Material Properties for Lockheed-Martin SMRD 100F-90C*



MATERIAL SELECTION MUST BE MADE USING PROPERTIES AT TEMPERATURE OF INTEREST

Figure 7. Material Characterization



GE MATERIAL PROPERTIES CAN BE ALTERED TO MEET SPECIFIC REQUIREMENTS. SMRD100F90C IS IDEAL FOR RELSAT.

*Data taken from "Analysis and Experimental Evaluation of RELSAT Damped Equipment Panels", C.V. Stahle, J.A. Staley, and J.C. Strain, Vibration Damping Workship II, AFWAL, March 1986.

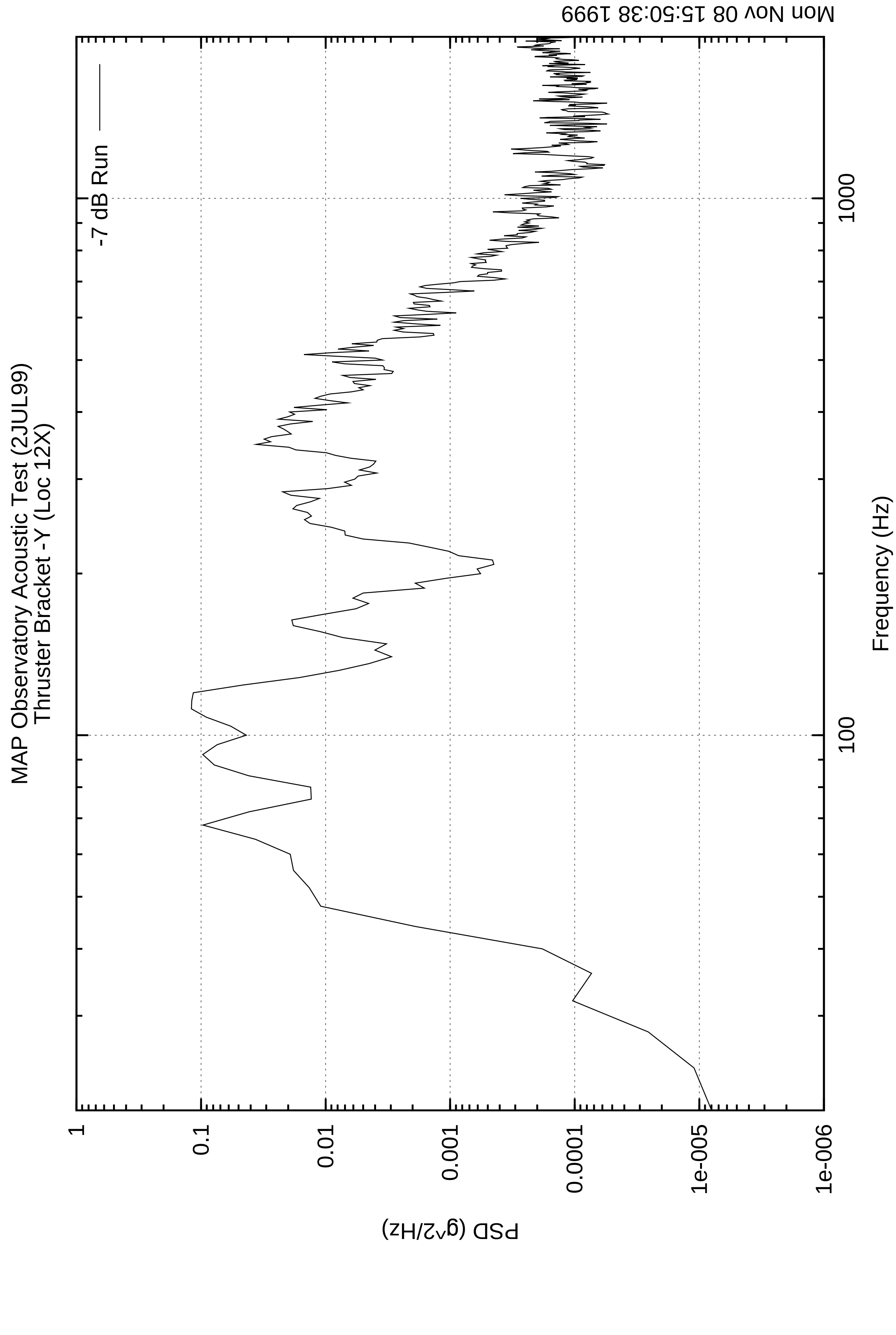
APPENDIX C
MAP "Intermediate" Observatory Acoustic Test
July 1999

- Acoustic Test Levels
- Top Deck Accelerometer PSD Data

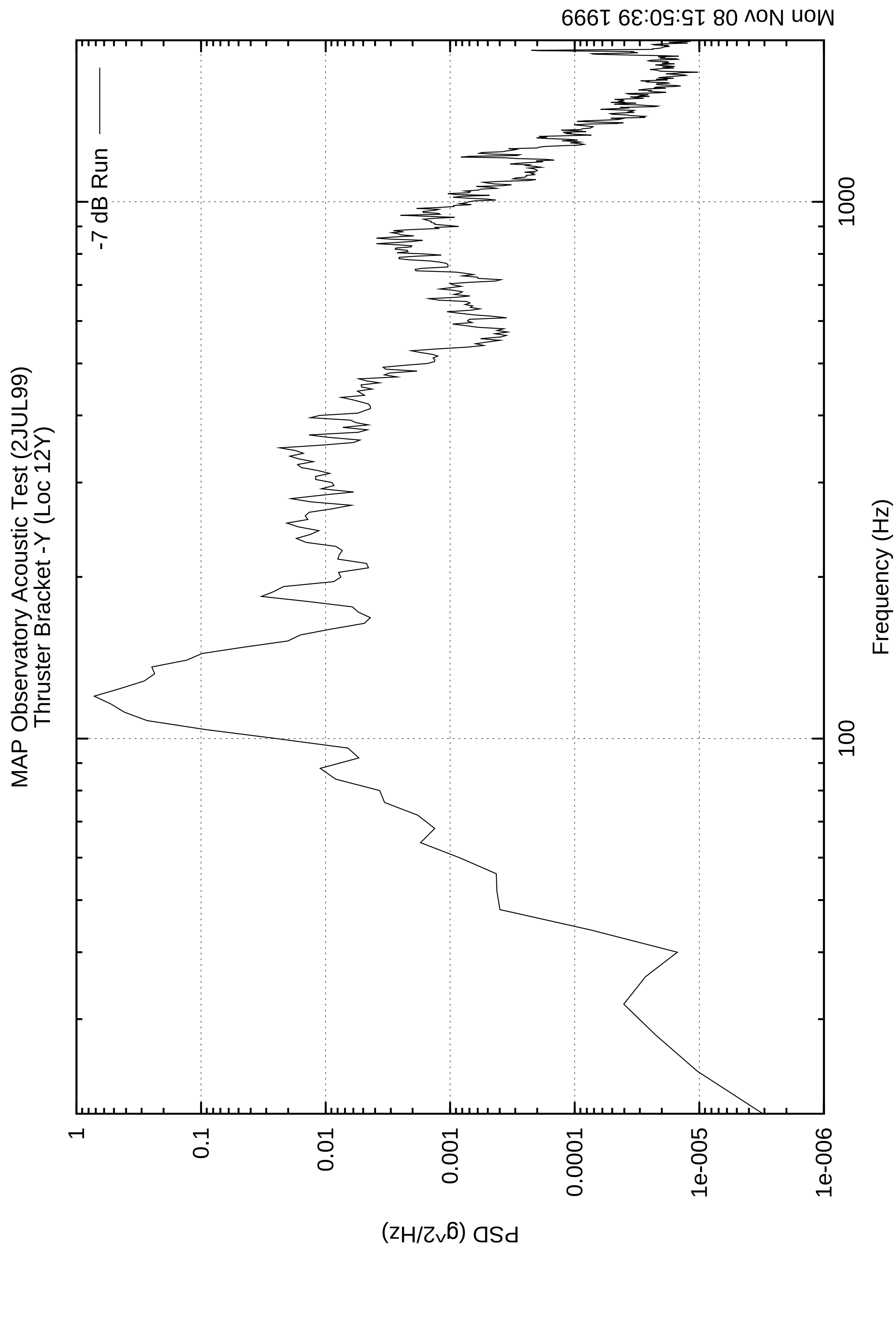
MAP Observatory Acoustic Test Levels

One-Third Octave Center Frequency (Hz)	Flight Level (dB)	Protoflight Level (dB)
31.5	117.9	120.9
40	121	124
50	125	128
63	126.6	129.6
80	127.2	130.2
100	128.3	131.3
125	127.8	130.8
160	124.9	127.9
200	126.5	129.5
250	130.6	133.6
315	128.6	131.6
400	126.7	129.7
500	127	130
630	125	128
800	122	125
1000	120	123
1250	118	121
1600	117	120
2000	116.5	119.5
2500	116	119
3150	115	118
4000	113.5	116.5
5000	111	114
6300	107	110
8000	103	106
10000	100	103
OASPL	138.6	141.6

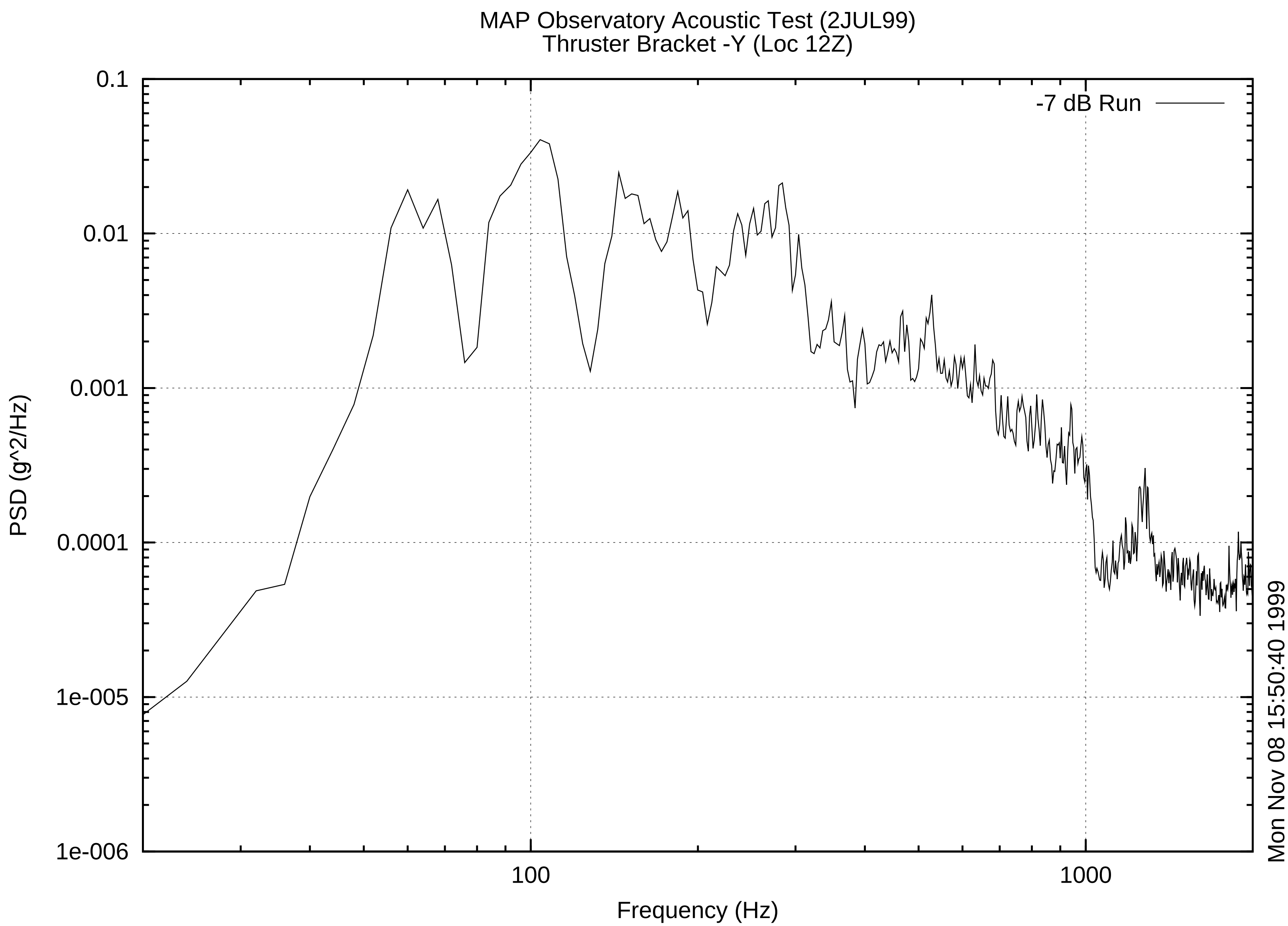
Acoustic test duration = 30 second

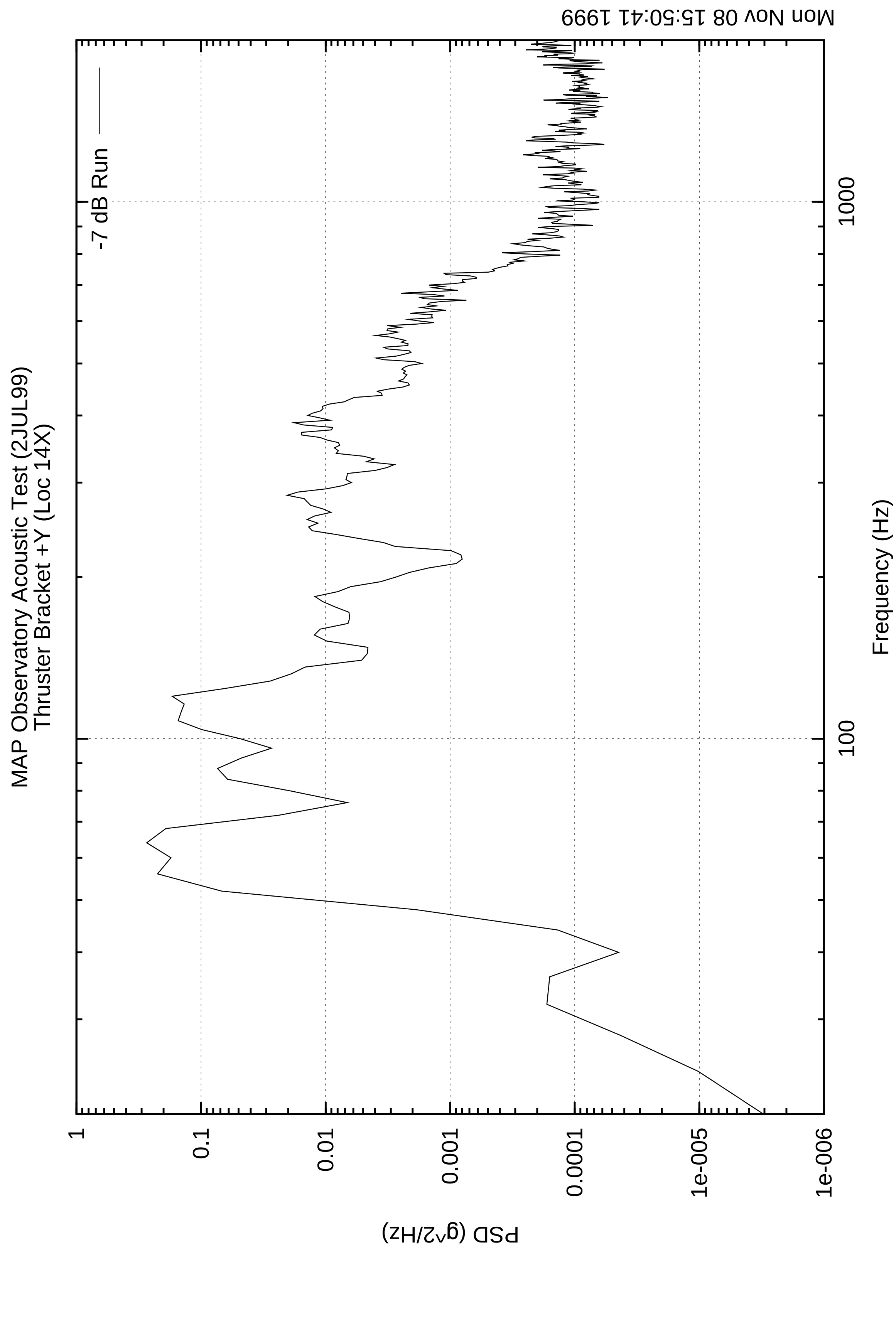


MAP Observatory Acoustic Test (2JUL99)
Thruster Bracket -Y (Loc 12X)
-7 dB Run
PSD (g^2/Hz)
1
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)
Mon Nov 08 15:50:38 1999

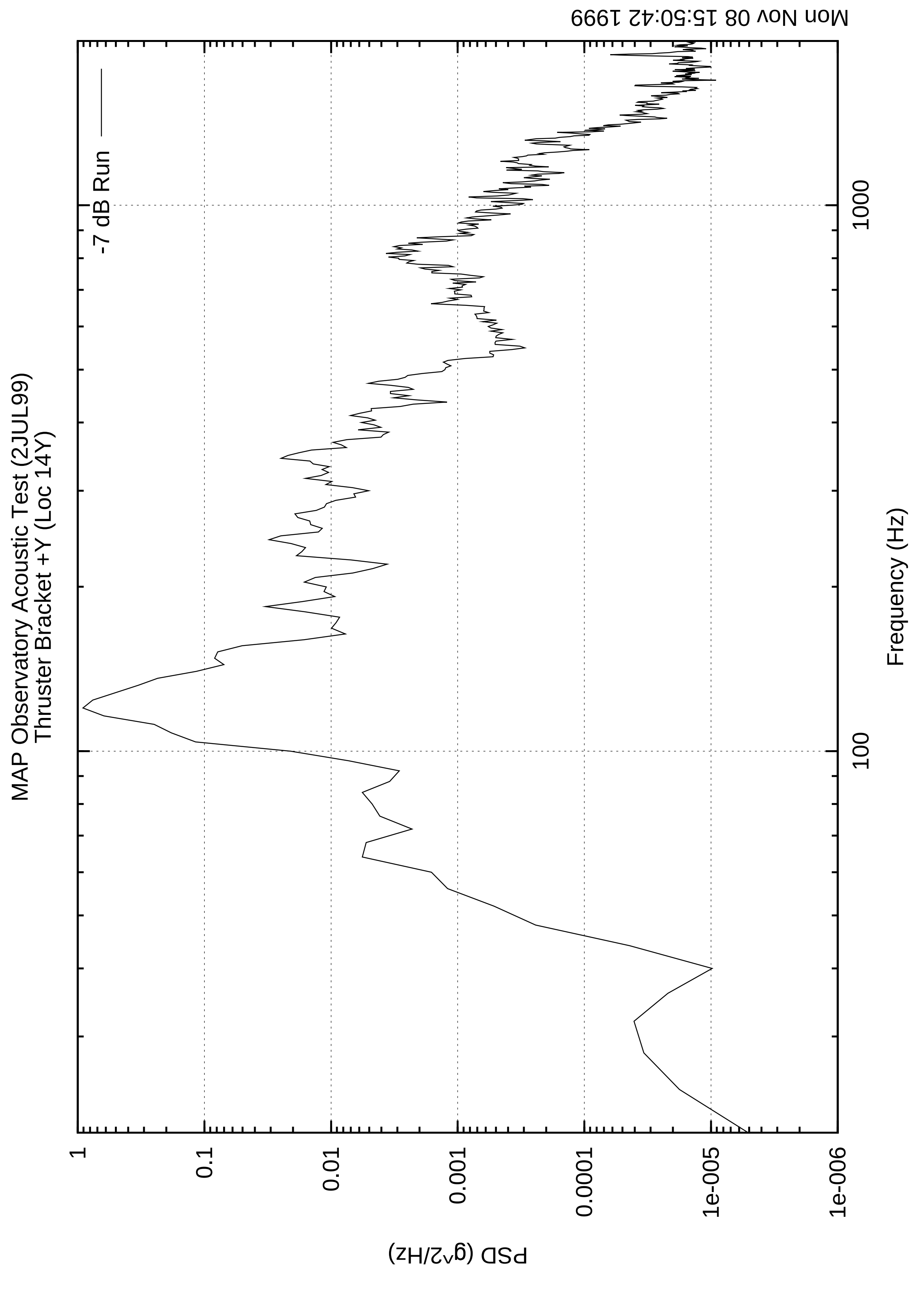


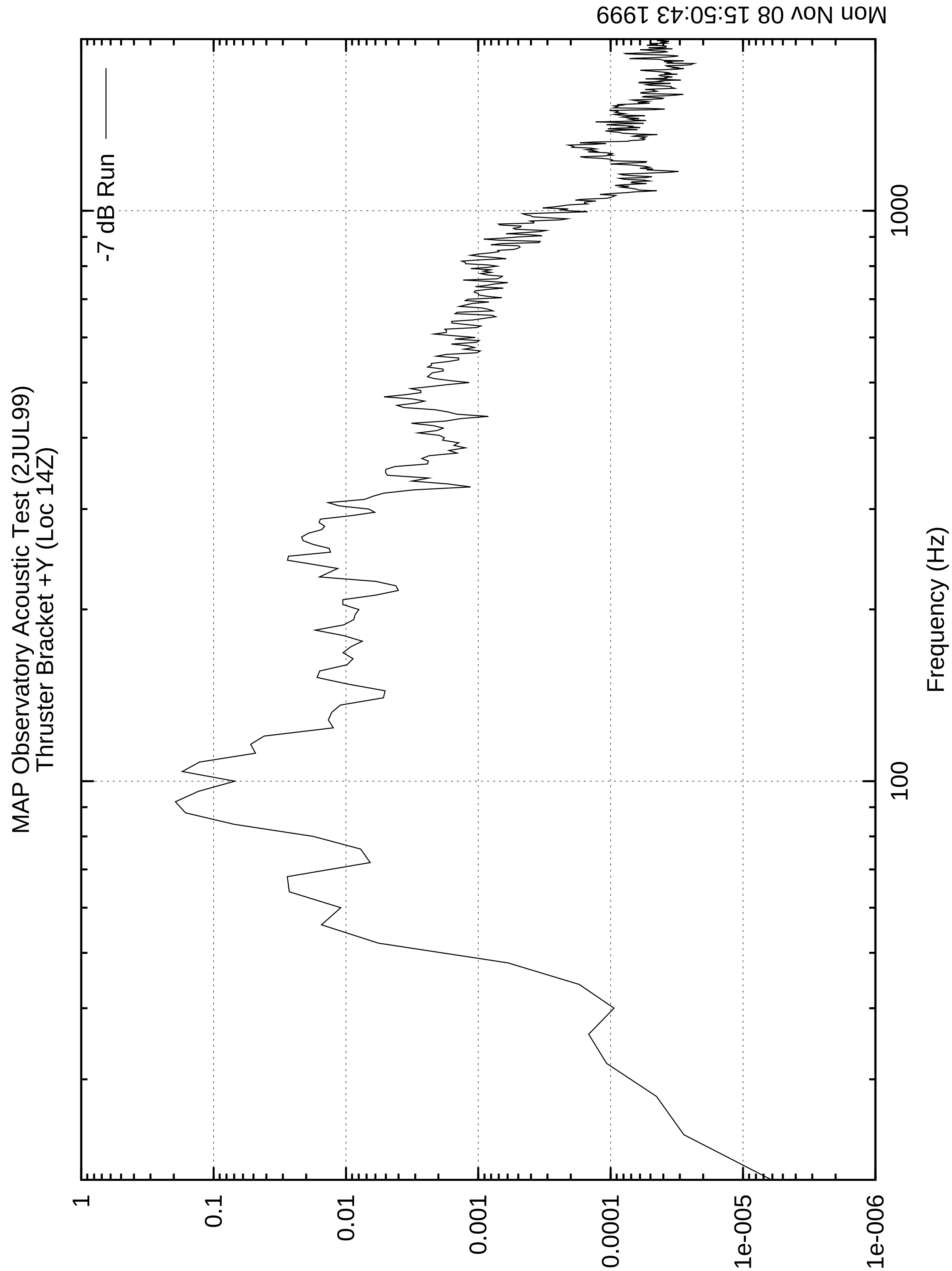
MAP Observatory Acoustic Test (2JUL99)
Thruster Bracket -Y (Loc 12Y)
Mon Nov 08 15:50:39 1999
-7 dB Run
PSD (g^2/Hz)
1
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)


MAP Observatory Acoustic Test (2JUL99)
Thruster Bracket -Y (Loc 12Z)
-7 dB Run
PSD (g^2/Hz)
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)
Mon Nov 08 15:50:40 1999

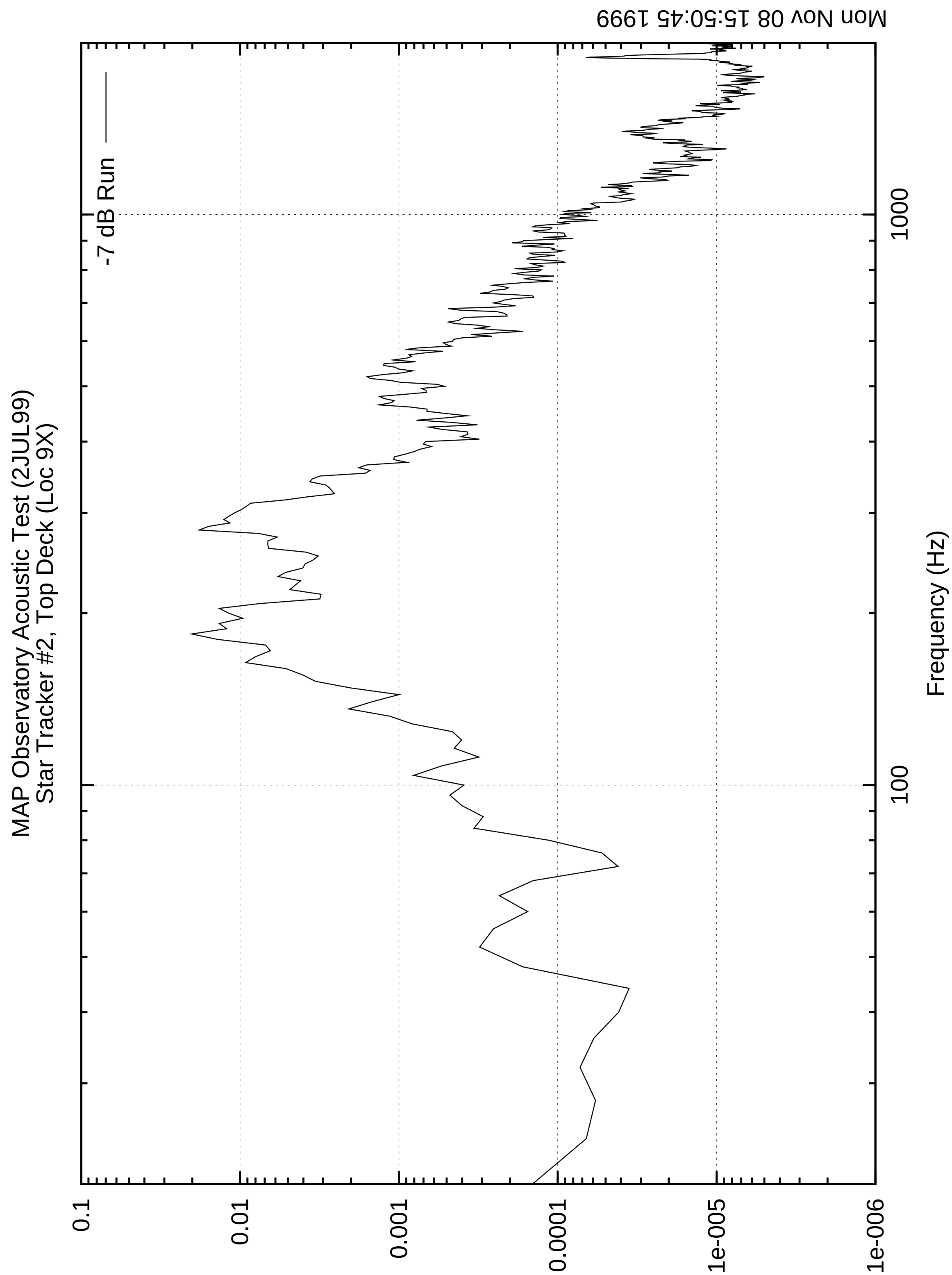


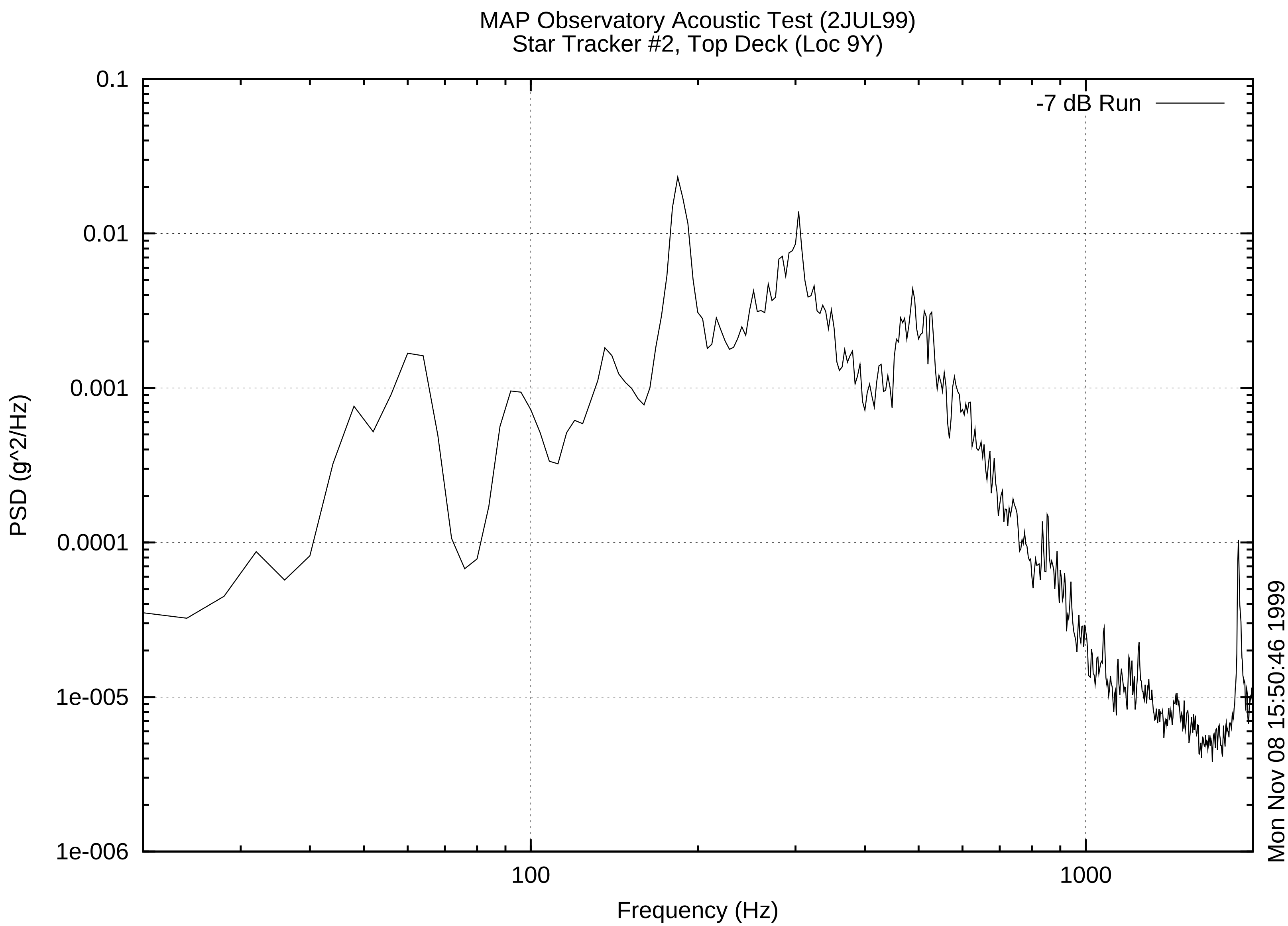
MAP Observatory Acoustic Test (2JUL99)
Thruster Bracket +Y (Loc 14X)
-7 dB Run
Frequency (Hz)
PSD (g^2/Hz)
1
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Mon Nov 08 15:50:41 1999


MAP Observatory Acoustic Test (2JUL99)
Thruster Bracket +Y (Loc 14Y)
Mon Nov 08 15:50:42 1999
-7 dB Run
PSD (g^2/Hz)
Frequency (Hz)
1
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000

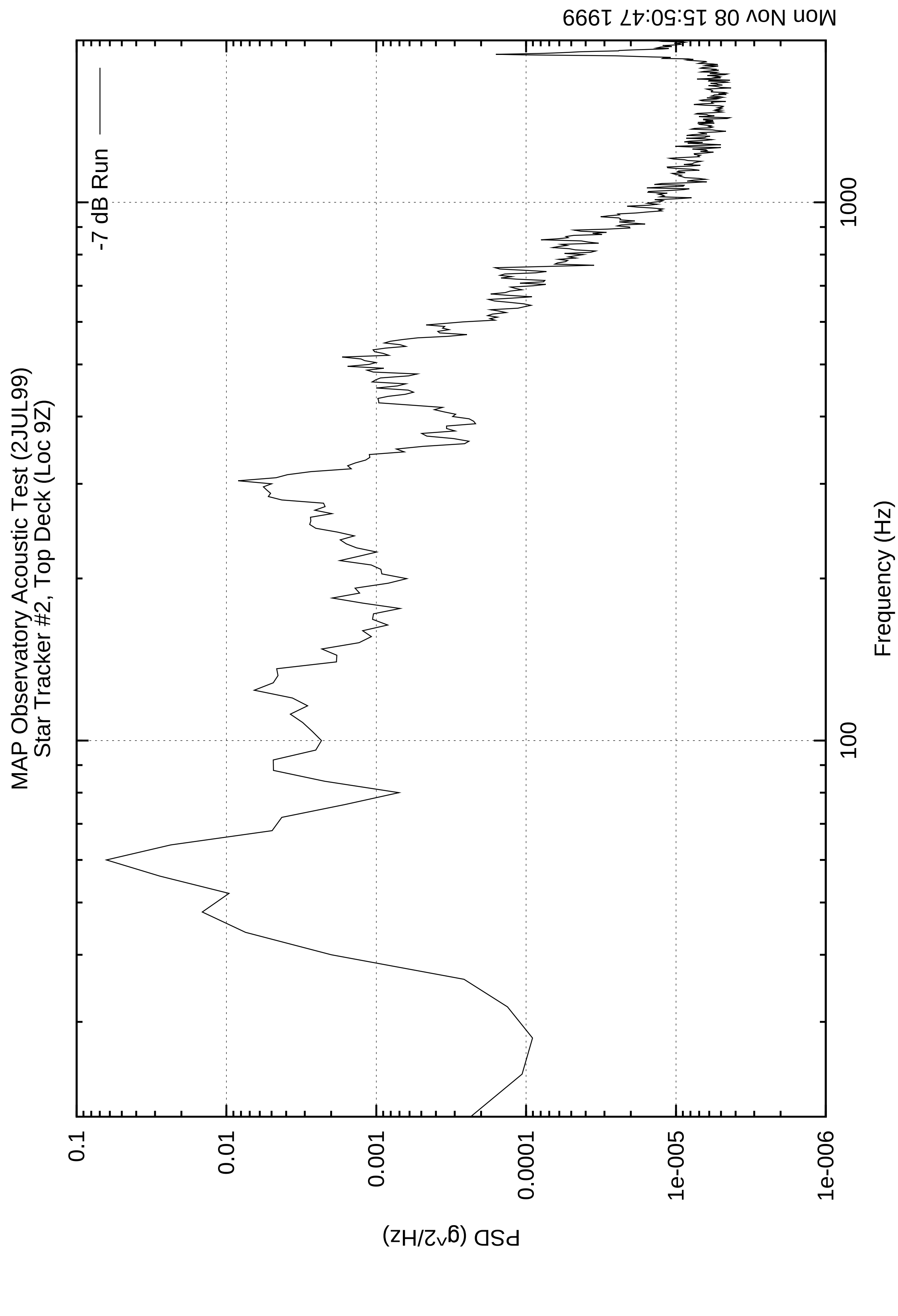


MAP Observatory Acoustic Test (2JUL99)
Thruster Bracket +Y (Loc 14Z)
Mon Nov 08 15:50:43 1999
-7 dB Run
PSD (g^2/Hz)
1
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)


MAP Observatory Acoustic Test (2JUL99)
Star Tracker #2, Top Deck (Loc 9X)
-7 dB Run
Mon Nov 08 15:50:45 1999
PSD (g^2/Hz)
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)



MAP Observatory Acoustic Test (2JUL99)
Star Tracker #2, Top Deck (Loc 9Y)
-7 dB Run
PSD (g^2/Hz)
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)
Mon Nov 08 15:50:46 1999


MAP Observatory Acoustic Test (2JUL99)
Star Tracker #2, Top Deck (Loc 9Z)
-7 dB Run
Mon Nov 08 15:50:47 1999
PSD (g^2/Hz)
0.1
0.01
0.001
0.0001
1e-005
1e-006
100
1000
Frequency (Hz)